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ATIKOKAN TGS AQUATIC STUDIES, 1981 to 1988 I: PHYSICAL CHARACTERISTICS

Report No 89-292-K

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ABSTRACT

This report integrates physical data collected during the course of studies conducted at Atikokan TGS and evaluates the effects of the station on these physical parameters. Operation of the station has led to substantial increases in currents in the connecting channels of the cooling circuit and these currents have likely had some influence on sediment erosion and deposition patterns. The thermal discharge has led to increases in the temperature of surface and bottom waters in Snow, Icy and Abie Lakes. The depth of the thermocline in these lakes has also increased. Snow and Icy Lakes and parts of Abie Lake and Marmion Lake (near Abie Lake) are ice free while the station is operating in the winter. The thermocline of Moose Lake has lowered substantially as a result of the removal of water by the station. Hypolimnetic oxygen depletion of most of the basins occurs during thermal stratification and to a lesser extent during the winter. Operation of the CCW pumps during station shutdowns in the winter replenishes oxygen concentrations of bottom waters in at least Snow Lake. Water clarity, as measured by Secchi depth, in Icy and Abie Lakes has decreased after station start-up but this observation is not consistent with measurements of turbidity in these lakes.

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34-146-492	837.321 ATI	December 20, 1989	89-292-K

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EXECUTIVE SUMMARY

ATIKOKAN TGS AQUATIC STUDIES, 1981 TO 1988
I: PHYSICAL CHARACTERISTICS

G.T. Haymes

Atikokan Thermal Generating Station (TGS) consists of one 200 MW lignite-fired unit. The condenser-cooling-water for Atikokan TGS is drawn from approximately the 10-m depth of Moose Lake and discharged at the surface into Snow Lake. The discharge water circulates through Snow, Icy, Abie and Marmion Lakes before returning to Moose Lake.

At Ontario Hydro generating stations, aquatic studies are conducted for three years prior to commissioning of the first unit and for three years following commissioning of the final unit. Less intensive studies are also conducted during the commissioning of the station. The purpose of these studies, as requested by Environmental Studies and Assessments Department, is to identify changes in components of the aquatic environment which may be attributable to the construction or operation of the generating station.

Pre and postoperational aquatic studies at Atikokan TGS were initiated in 1981 and were completed in 1988. The design of the postoperational studies was based primarily on the results of a workshop held in 1984 to discuss the potential impacts of Atikokan TGS on the environment. This report integrates the physical data (temperature, dissolved oxygen, substrates, currents and water clarity) collected during the course of the study and evaluates the effects of the station on these physical parameters.

With three shift operation, the daily mean temperature rise across the station was 10 to 11°C. The maximum temperature of the effluent was 32.8°C for at least one hour on July 31, 1988. The highest daily mean was 32.0°C on four occasions at the end of July and the beginning of August, 1988.

The temperature profiles of Snow Lake tended to be much more erratic than those taken in 1981 and 1983 due primarily to the variable operation of the station (i.e. pumps running and producing heat, pumps running and not producing heat, and pumps not running). The erratic nature of the profiles was less apparent in Icy and Abie Lakes and absent from the Marmion Lake locations. In Moose Lake, the 1988 profiles were substantially different than those from 1981 and 1983. The epilimnion was substantially larger in 1988 than prior to pump operation.

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Operation of the station tended to increase the depth of the thermocline in the first three lakes of the cooling circuit (Snow, Icy and Abie). In Moose Lake, the depth of the thermocline increased from approximately 5 m in 1981 and 1983 to 15 m in 1986 and 1988. This was primarily due to the withdrawal of water from Moose Lake by the station.

While the station was operating, the near surface temperatures of each of Snow, Icy and Abie Lakes increased by approximately 4, 2 and 1°C in June and 8, 4 and 3°C in the fall. In addition, the temperatures of the hypolimnion were also increased while the station was operating.

Winter profiles were taken in March, 1989 when the CCW pumps were operating but no heat was being produced. The profiles from the first lakes of the cooling circuit were homeothermal at 1 to 2°C. The winter profiles were similar to those measured during the preoperational phase.

Based on casual observations prior to station operation, ice generally began to form on the study lakes in November or December and began to break up from mid-April to the beginning of May. Ice on the smaller lakes tended to clear earlier (approximately a week) than Marmion Lake. After the station began operating, Snow and Icy Lakes did not completely freeze over, although some shore ice formed on Icy Lake. Abie Lake would freeze over almost completely at the beginning of winter but gradually a channel of open water through Abie Lake into Marmion Lake would form and widen as the winter progressed leaving only the two bays of Abie Lake, outside the main current, frozen by the end of the winter. When the station shut down and the pumps were shut off during the winter, a thin cover of ice would form over the open areas relatively quickly.

Hypolimnetic oxygen depletion was apparent in all of the study basins during the preoperational phase. In the first three lakes in the cooling circuit the minimum depth of oxygen depletion tended to closely follow the depth of the thermocline. Much of the hypolimnion was depleted of oxygen from July until stratification disappeared in September or October. With the lowering of the thermocline during 1988, the minimum depth of oxygen depletion was deeper, particularly after July. Although more of the water column was oxygen rich in 1988, the extent of the hypolimnion that was oxygen depleted actually increased. A similar trend was also apparent at some of the Marmion Lake (Marmion South and Central and Anderson Dam) locations in 1988 but the increased depth of oxygen depletion occurred later in the summer (August or September).

In Moose Lake in 1988 oxygen depletion was apparent at the thermocline with levels increasing in the top few meters of the hypolimnion indicating high heterotrophic activity at the thermocline.

In Snow and Icy Lakes the initial stages of winter oxygen depletion were apparent in the October measurements during 1988. This oxygen depletion was coincident with the start up of the station after a September shut down. This evidence suggests that oxygen depletion of the hypolimnions of Snow and Icy Lakes will occur during the winter whenever the operating station can maintain thermal stratification. Reduced hypolimnetic oxygen concentrations were also recorded during winters of the preoperational years. Although station operation may contribute to winter hypolimnetic deoxygenation when it is producing heat, it would tend to recharge the deeper strata with oxygen when the station is pumping but not producing heat such as when the station is being shut down as occurred during March, 1989. When the pumps are operating but heat is not being produced, cold oxygenated water is passed through the station and the discharge is mixed throughout the water column of Snow Lake as opposed to the heated discharge which is buoyant and spreads across the surface of the lake.

Water transparency, measured as Secchi depth, tended to be similar among years at most locations. The only exceptions were Icy, Abie and possibly Moose Lakes where Secchi depths

tended to be shallower during 1988 than similar measurements during the preoperational phase. The lower Secchi depths in Icy and Abie Lakes after start-up of the station are not consistent with the observed reduction in turbidity in Icy Lake and the lack of trend in Abie Lake. The trend toward lower clarity in Moose Lake is likely the result of the breaching of Anderson Dam. With the station operating, water from Anderson Dam, where the lowest Secchi depths were recorded, is drawn into Moose Lake.

Spring (April and May) flows and currents in the channel between Ski and Icy Lakes which is not influenced by the station discharge were quite variable depending on the timing and magnitude of the spring freshet. Similarly, currents and flows in the connecting channels of the cooling circuit were also variable and dependent on the timing and extent of the spring freshet prior to commissioning of the CCW pumps; however, while the pumps are operating, flows and average currents are now dependent almost entirely on the volume of water being pumped by the station. Consequently, flows and currents are considerably higher and less variable in the connecting channels.

Although studies were not conducted to examine changes in the sediment erosion and deposition in the cooling circuit as a result of station operation, one would expect that establishment of the cooling circuit and its associated currents would result in some changes in erosion and deposition patterns. Casual observations during other aspects of the Atikokan study did indicate that sediment deposition areas were established downstream of some of the connecting channels where currents began to dissipate.

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ATIKOKAN TGS AQUATIC STUDIES, 1981 TO 1988
I: PHYSICAL CHARACTERISTICS

1.0 INTRODUCTION

Atikokan Thermal Generating Station (TGS) consists of one 200 MW lignite-fired unit. The condenser cooling water for Atikokan TGS is drawn from approximately the 10-m depth of Moose Lake and discharged at the surface into Snow Lake. The discharge water circulates through Snow, Icy, Abie and Marmion Lakes before returning to Moose Lake (Figure 1).

At Ontario Hydro generating stations, aquatic studies are conducted for three years prior to commissioning of the first unit and for three years following commissioning of the final unit. Less intensive studies are also conducted during the commissioning of the station. The purpose of these studies, as requested by Environmental Studies and Assessments Department, is to identify changes in components of the aquatic environment which may be attributable to the construction or operation of the generating station.

Pre and postoperational aquatic studies at Atikokan TGS were initiated in 1981 and were completed in 1988. Results of studies conducted since 1981 are presented in Haymes 1983, 1984, 1985a, 1985b and 1986 and Haymes and Kwik 1987 and 1988. The design of the postoperational studies was primarily based on the results of a workshop held in 1984 to discuss the potential impacts of Atikokan TGS on the environment (Greig et. al. 1984).

The study area consists of the five lakes of the cooling circuit; Snow, Icy, Abie, Marmion and Moose and two locations outside the direct influence of the cooling circuit, Slush Lake and Lower Seine Bay on Marmion Lake (Figure 1).

This report integrates the physical data (temperature, dissolved oxygen, substrates, currents and water clarity) collected during the course of the study and evaluates the effects of the station on these physical parameters. The results of continuous temperature monitoring are reported elsewhere (Lawler 1988, Lawler and Moroz 1989).

1.1 Historical Perspective

Prior to the twentieth century the study area was part of the Seine River Valley, as it flowed from Lac des Milles Lacs into Sawbill Lake, through Moose Lake, Steep Rock Lake and finally into Rainy Lake (Ontario Hydro 1975).

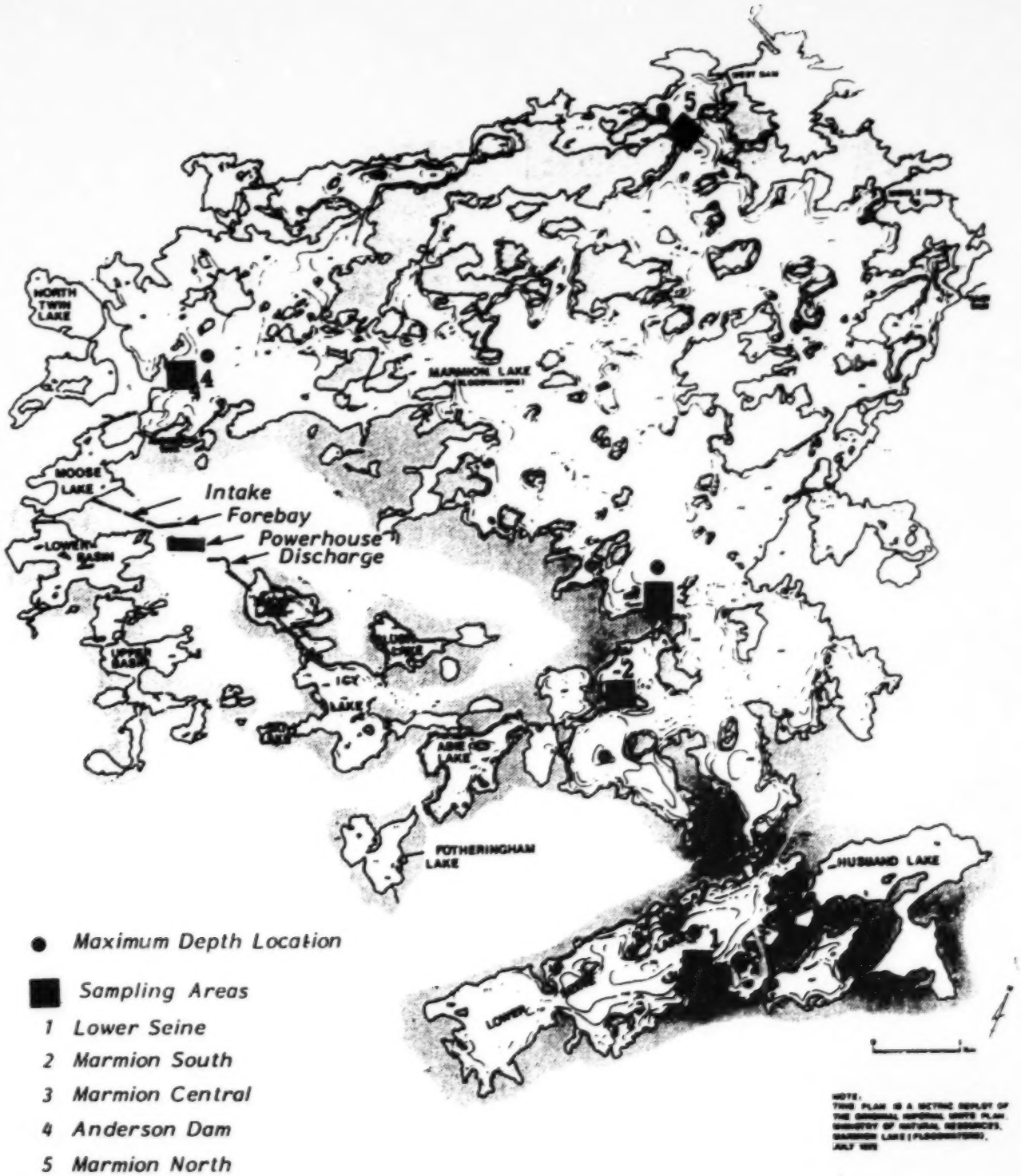


FIGURE 1

ATIKOKAN SAMPLING LOCATIONS

In the late 1920's, the Minnesota Ontario Pulp and Paper Company built eight dams on the Seine River in the area of Moose Lake to provide head for a hydro-electric plant at Steep Rock Falls. With the discovery of iron ore under Steep Rock Lake and consequent strip mining operations of the Steep Rock and Caland mining companies, additional dams were completed which resulted in the diversion of the flow of the Seine River west, through Clearwater Lake (Finlayson Lake) into the western arm of Steep Rock Lake. This resulted in the partial or total isolation of Marmion and Moose Lakes and the central and eastern arms of Steep Rock Lake from the Seine River, and the flooding of a large tract of land which is now part of Marmion Lake.

To allow the strip mining of Steep Rock Lake the central and eastern arms were dewatered and the over-burden was dredged and deposited in the upper and lower basins of Moose Lake and the southern portion of Marmion Lake.

By 1981, the mining operations had been closed for several years and the large pits were being allowed to refill naturally.

1.2 Major Construction Activities

The construction of Atikokan TGS required several major physical perturbations to the cooling water circuit. These are detailed below.

To allow the construction of the intake tunnel, Moose Lake water levels were lowered in excess of 10 metres prior to 1981. This reduction returned water levels to near the original elevation of the Seine River in the area. The lake was refilled by pumping water from Marmion Lake during 1982. After refilling of Moose Lake, Anderson Dam, separating Marmion and Moose Lakes, was breached.

Marmion Lake has been used for water storage to provide head for power plants on the Seine River. Water entered into Marmion Lake at the West Dam (Marmion North, Figure 1) from Raft Lake and the Seine River. To further isolate Marmion Lake from the Seine River an impervious dam was constructed at the West Dam location. With the closure of the West Dam the only location for mixing of waters between Raft Lake and Marmion Lake is the Spillway Dam. Most of the water movement is from Marmion Lake to Raft Lake although movement into Marmion Lake is possible depending on the operation of the downstream plants and the size of the spring freshet. The construction of the West Dam has resulted in the stabilization of water levels in Marmion Lake.

In 1981, at the beginning of the project, the channel between Icy and Abie Lakes was obstructed by a beaver dam while the channel between Abie and Marmion Lakes was relatively shallow (approximately 1 m). The dam at the outflow of Icy Lake was removed and the channel was widened. Similarly, the channel at the outflow of Abie Lake was deepened. This had the effect of maintaining the level of Abie Lake at the level of Marmion Lake and reducing the level of Icy Lake by less than a meter. It also allowed fish to easily move between Marmion, Abie and Icy Lakes.

In 1981, the outflow of Snow Lake into Icy Lake consisted of a series of beaver dams and small ponds. A weir was constructed at the outflow and a riffle area was created below the weir in the channel into Icy Lake. During construction of the weir in 1982, the water level of Snow Lake was lowered by approximately 2 m. The weir maintains water levels in Snow Lake slightly below historical levels. Although fish cannot move into Snow Lake from Icy Lake, downstream movement of juvenile and adult fish from Snow Lake is possible.

1.3 Station Operation

Electrical output of Atikokan TGS for the postoperational survey years 1986 through 1988 is illustrated in Figures 2 to 4. Through the first half of 1986 the station operated two shifts per day, five days per week increasing to three shifts by the end of the year. In 1986 a major outage occurred from mid-June through mid-August. In 1987 five- day operation continued through the end of August changing to 7-day operation for the remainder of 1987 through 1988. Extended outages occurred in March, April and September, 1987 and in March June and September of 1988.

2.0 METHODS

2.1 Bathymetry

Bathymetric maps of the study area lakes, not previously mapped, were compiled in 1981 using a Furuno FE-400 recording echo sounder. Measurements were transposed from chart to contour map using the MNR proportional divider technique. A number of morphometric parameters were calculated from these maps.

2.2 Temperature and Dissolved Oxygen

Temperature and dissolved oxygen profiles were measured at least monthly in 1981, 1983, 1986 and 1988 and seasonally in 1982, 1984 and 1985 (1987 results are unreliable due to persistent equipment failures). Measurements were taken at 1 m intervals at 10 locations; Snow, Icy, Abie, Slush and Moose Lakes and in Marmion Lake at Marmion South, Central and North, Lower Seine and Anderson Dam (Figure 1). Measurements were made with a Hydrolab recorder (series 4000).

2.3 Transparency

Secchi depth measurements were taken during site visits in 1981, 1983 and in 1988.

2.4 Currents

Current measurements, from which flow was calculated, in the connecting channels of the cooling circuit and from Ski to Icy Lake were made in 1982, 1984, 1986 and 1987. Measurements were taken middepth at 1 m intervals along a cross-section of the channel at its narrowest point. Flows were calculated using methods described in Dodge et al (1980).

2.5 Substrates and Sedimentation

A substrate map of the study area was constructed in 1981 on the basis of SCUBA diver observations along 58 transects, supplemented by grab samples and casual observations. Casual observations of changes in sedimentation patterns as a result of construction or operation of Atikokan TGS were made during other aspects of the study.

3.0 RESULTS

3.1 Morphometric Characteristics

Bathymetric maps were prepared for each of the study lakes during 1981 (Haymes 1983). Changes in water level as a result of cooling circuit construction occurred in Snow, Icy and

FIGURE 2

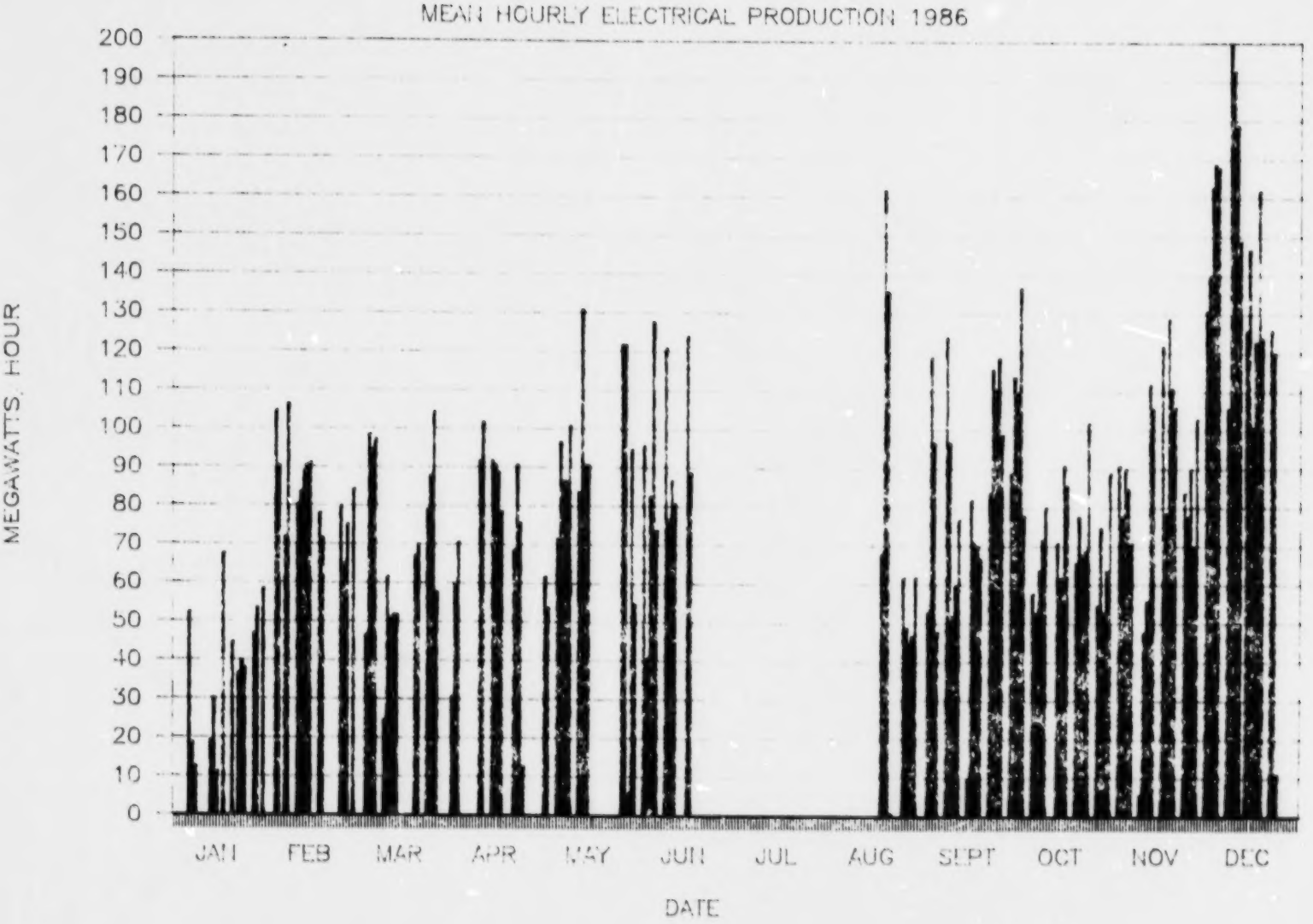

MEAN HOURLY ELECTRICAL PRODUCTION 1986
MEGAWATTS, HOUR
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEPT
OCT
NOV
DEC
DATE

FIGURE 3

MEAN HOURLY ELECTRICAL PRODUCTION 1987

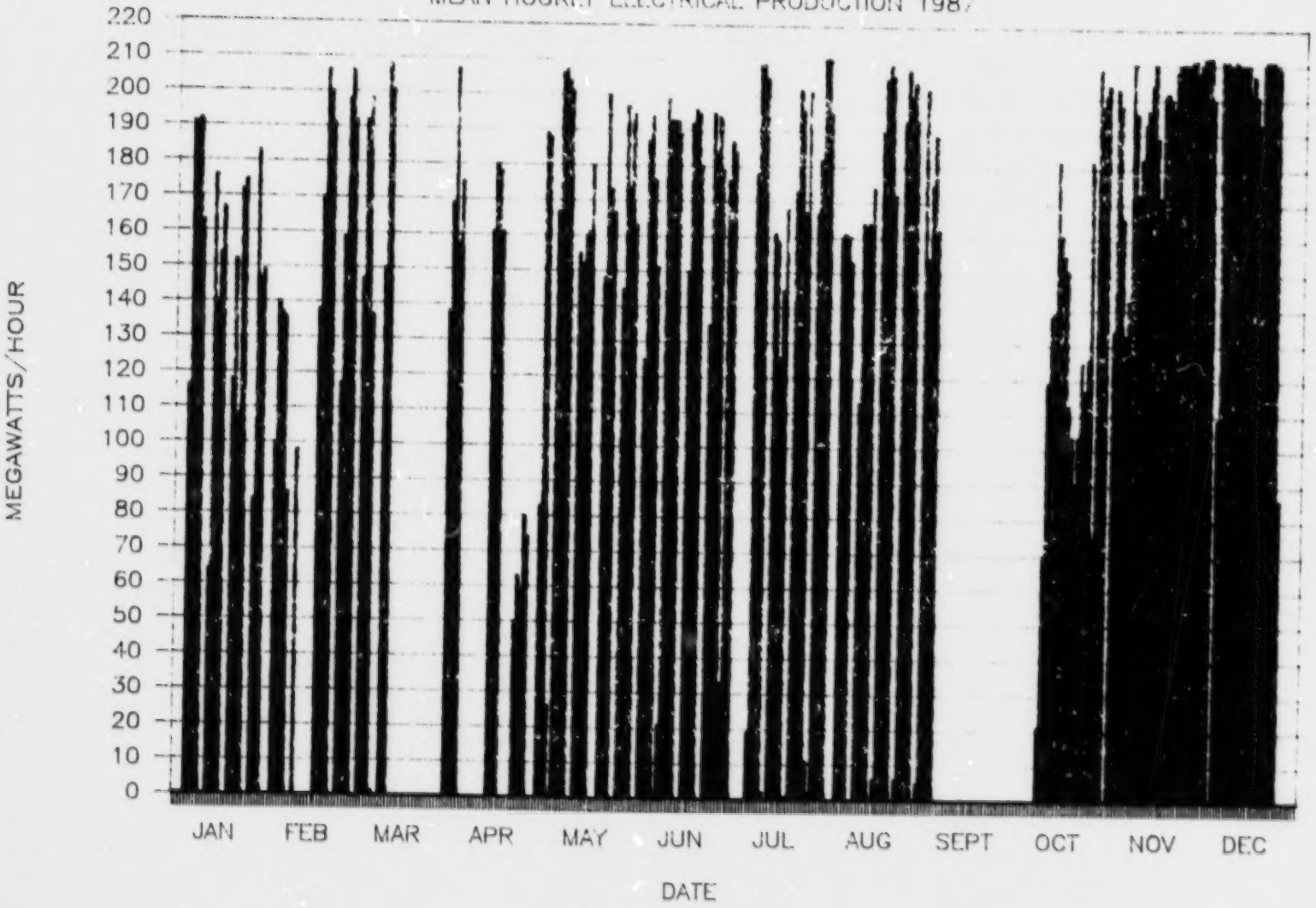
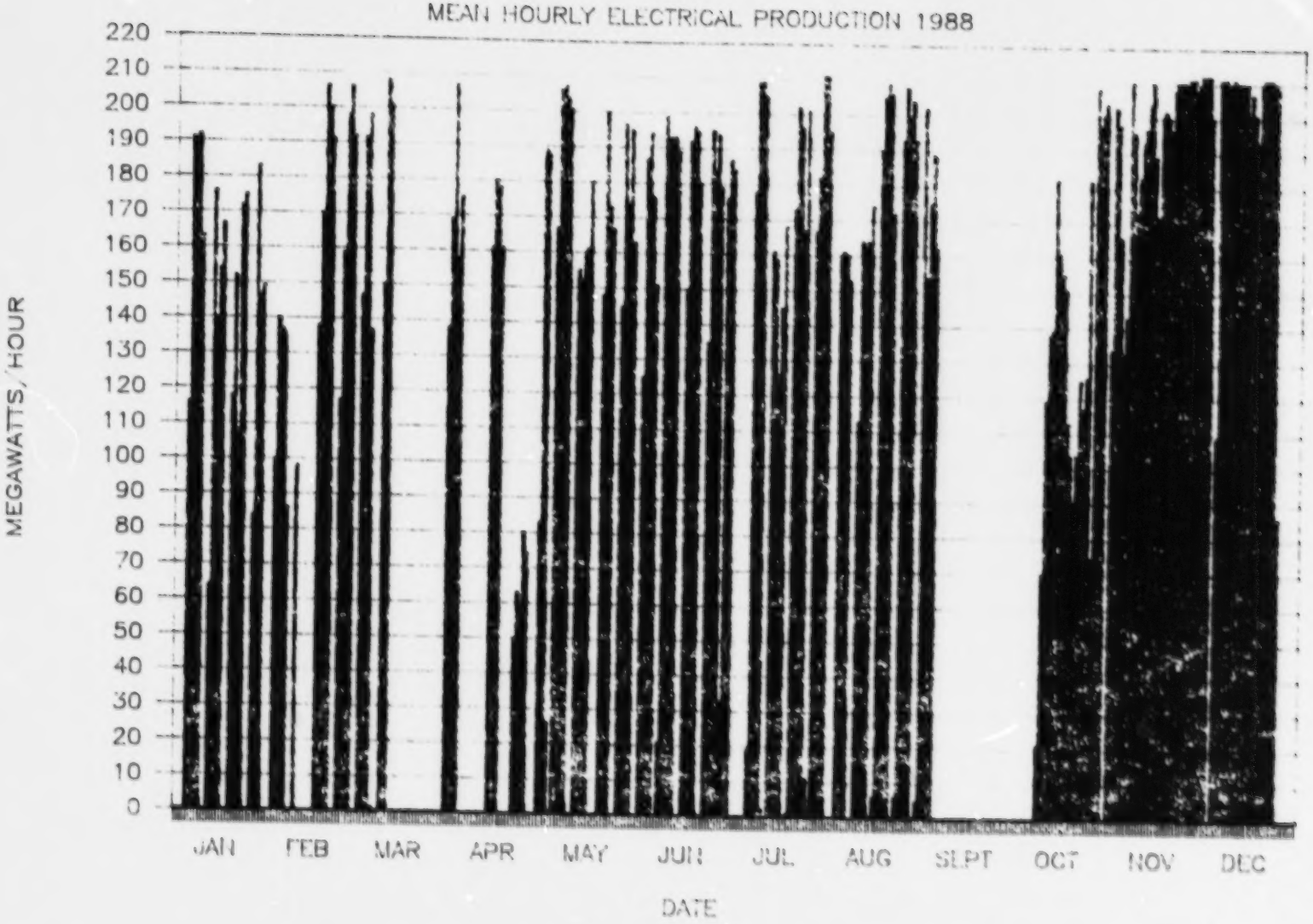


FIGURE 4


MEAN HOURLY ELECTRICAL PRODUCTION 1988
MEGAWATTS/HOUR
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
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Moose Lakes. Several morphometric characteristics of the cooling circuit lakes were calculated on the basis of the bathymetric maps. These are listed in Table 1.

TABLE 1

MORPHOMETRIC CHARACTERISTICS OF THE STUDY LAKES
(Parameters Based on Original Water Levels)

LAKES

	Snow	Icy	Abie	Slush	Marmion	Moose
Water Level (m)						
Original	417.5	416.5	415.5	417	415.5	413.2
Operating	418.6	415.5	415.5	417	415.5	415.5
Surface Area (ha)	41	101	94	28	10516	60
Perimeter (km)	3	9	8	3	455	8
Volume (m^3*10^4)	203	558	452	274	71385	786
Mean Depth (m)	5.0	5.5	4.8	9.7	6.8	13.2
Shoreline Development Factor	1.4	2.5	2.3	1.6	12.5	2.8

With the construction of the weir at the Snow Lake outlet, excavation of the outflow of Icy Lake and the removal of Anderson Dam between Marmion and Moose Lakes, the water level of Snow and Moose Lakes were raised while that of Icy Lake was lowered.

3.2 Temperature and Dissolved Oxygen

Temperature Rise Across the Station

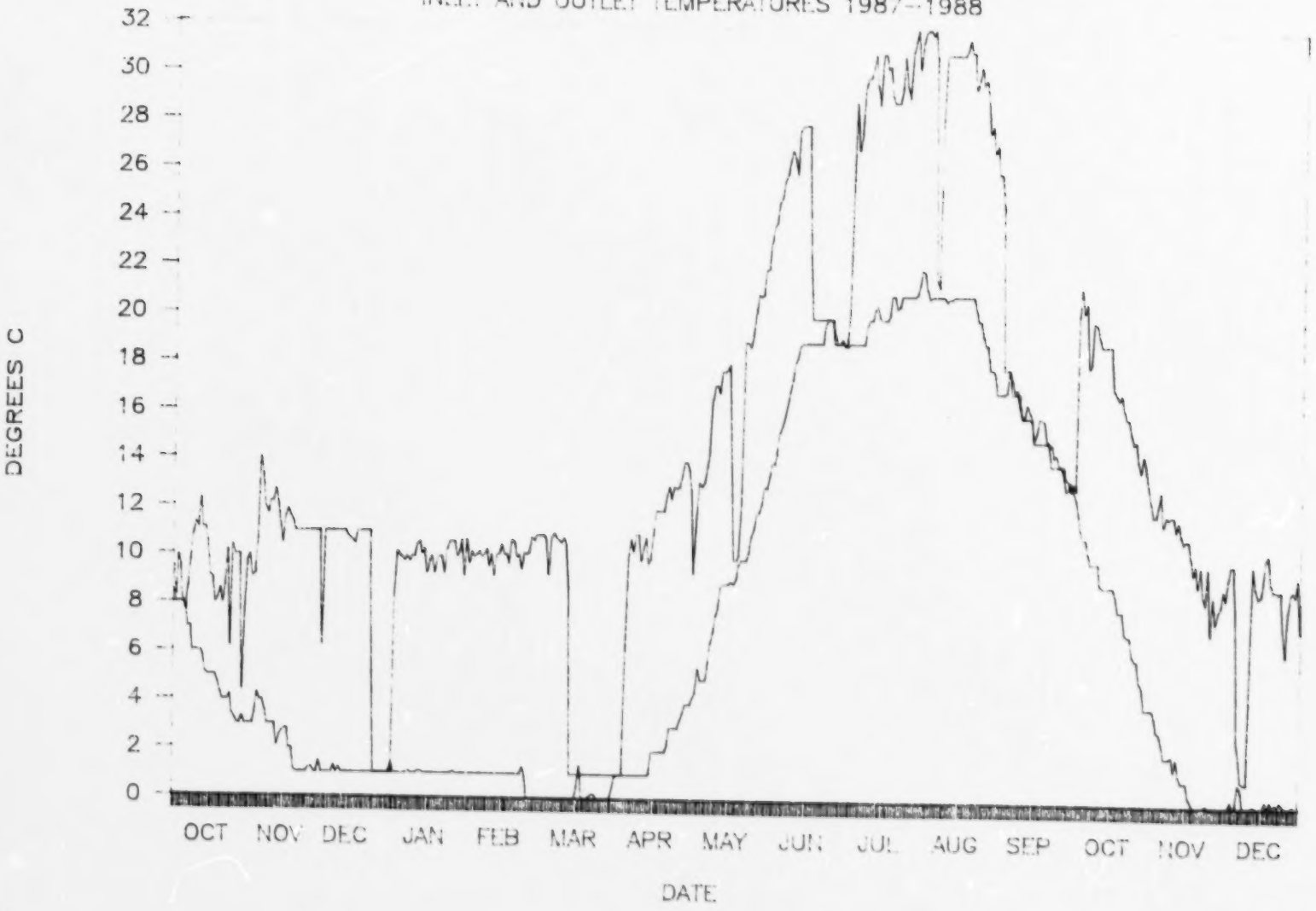
Inlet and outlet temperatures measured by the station were available for the period from October 1987 through 1988 (Figure 5). With three shift operation the daily mean temperature rise across the station was 10 to 11°C. The maximum temperature of the effluent was 32.8°C for at least one hour on July 31, 1988. The highest daily mean was 32.0°C on four occasions at the end of July and the beginning of August, 1988.

Temperature

Temperature and dissolved oxygen measurements taken during 1988 and March 1989 are listed in Appendix 1. These are compared to similar profiles taken in 1981 and 1983 in Figures 6 through 12.

FIGURE 5

INLET AND OUTLET TEMPERATURES 1987--1988



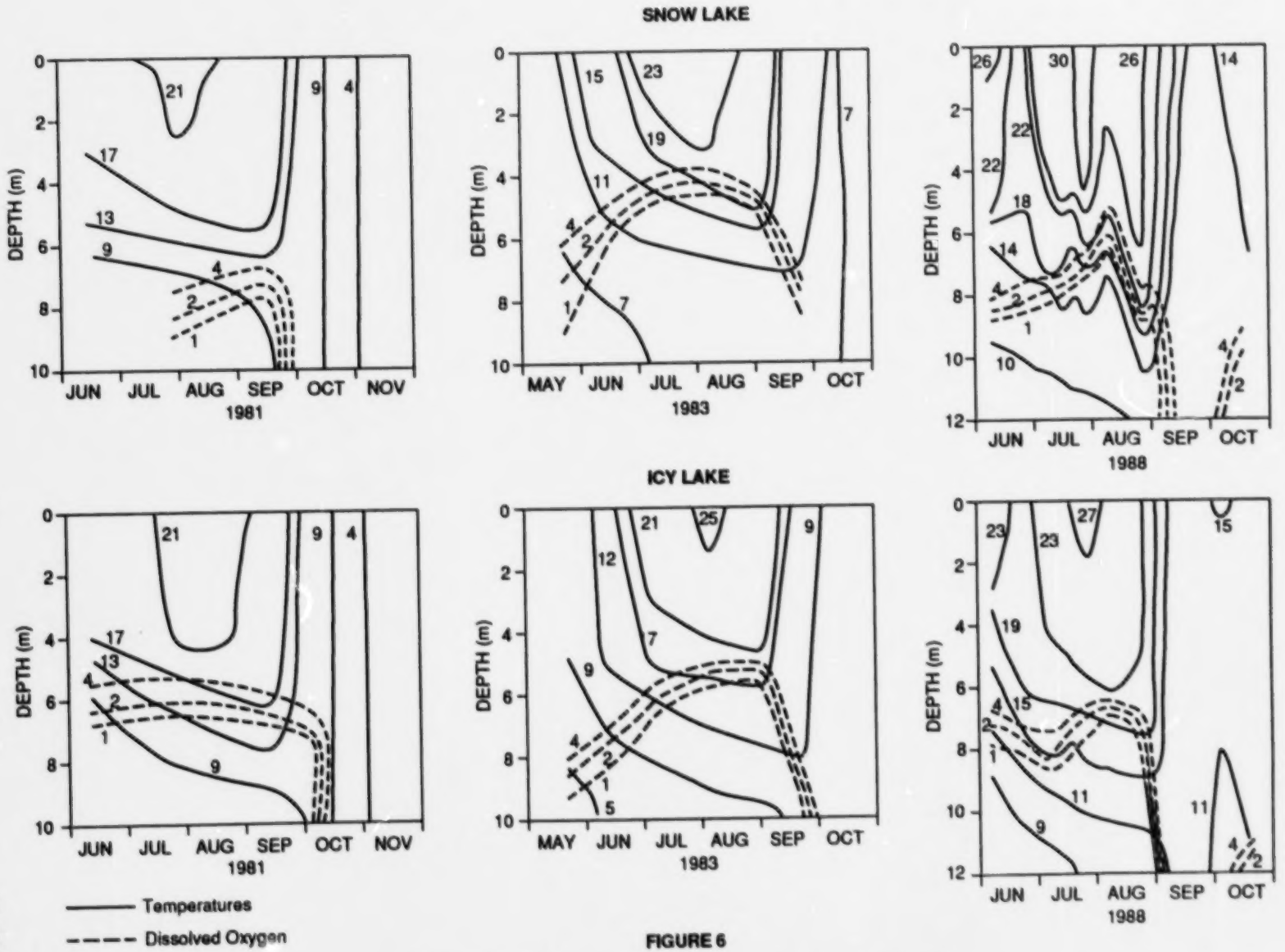


FIGURE 6

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES OF SNOW AND ICY LAKES - 1981, 82 AND 88

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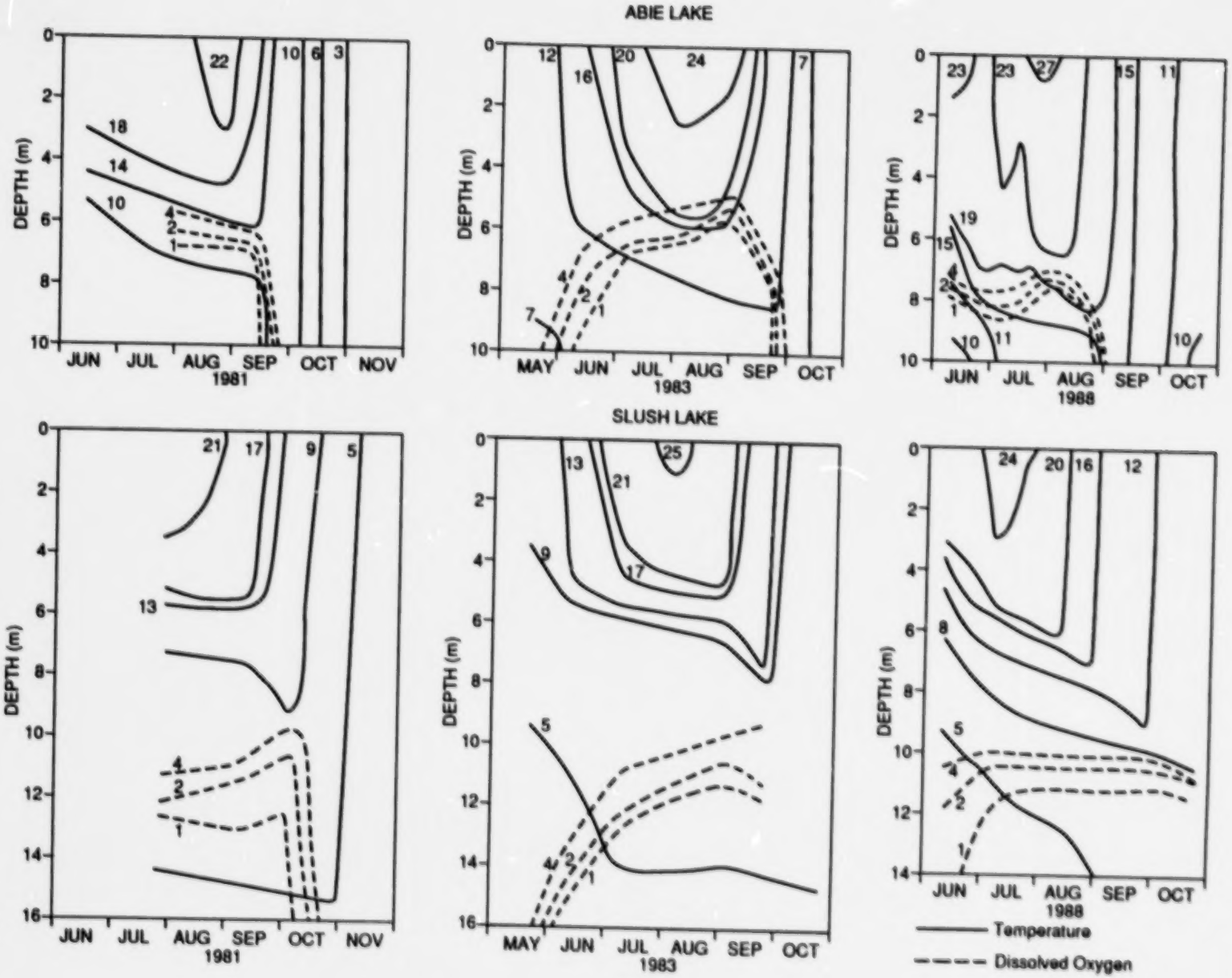

FIGURE 7

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES OF ABIE AND SLUSH LAKES - 1981, 83 AND 88

89-292

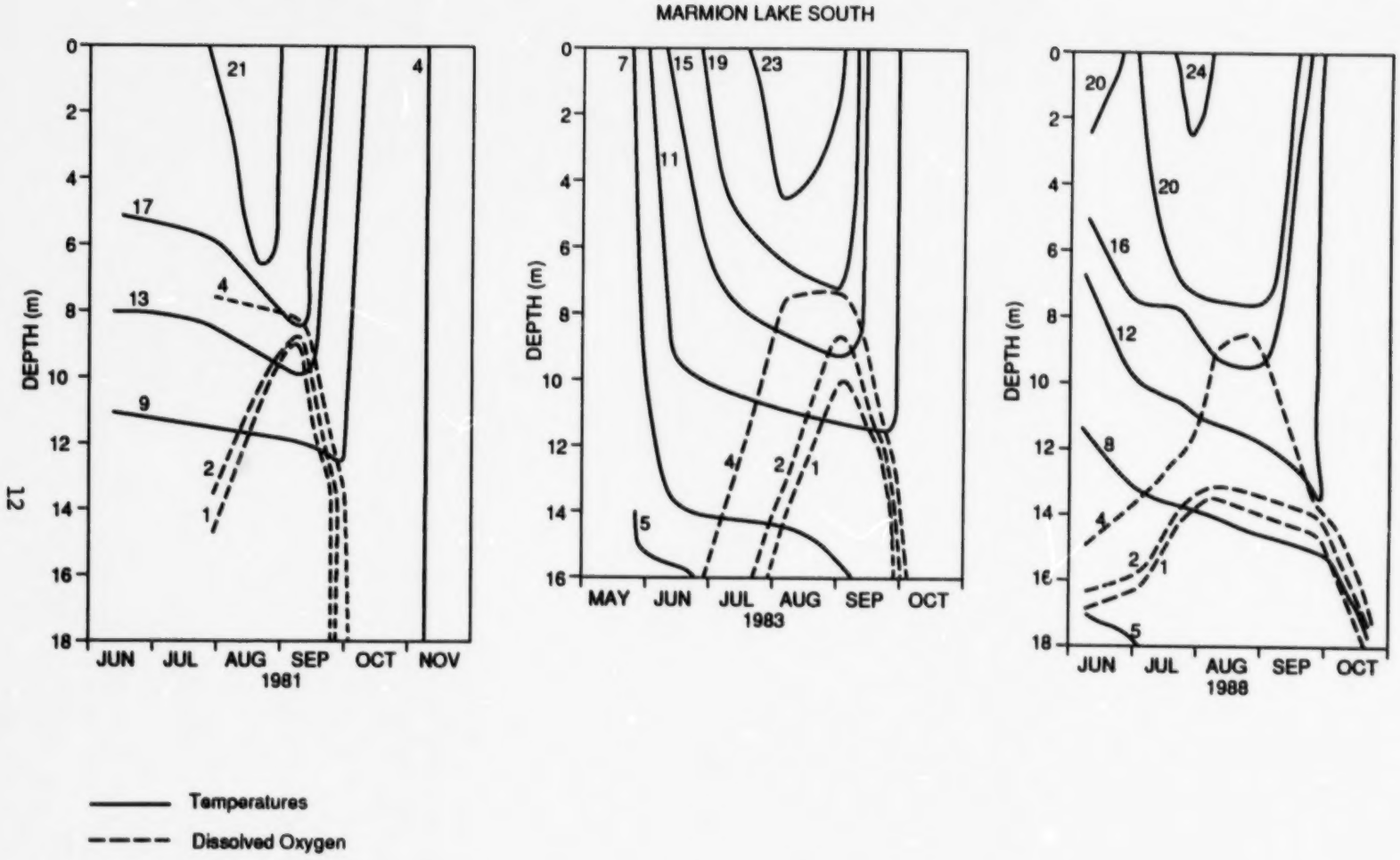

FIGURE 8

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES OF MARMION LAKE SOUTH - 1981, 83 AND 88

89-292

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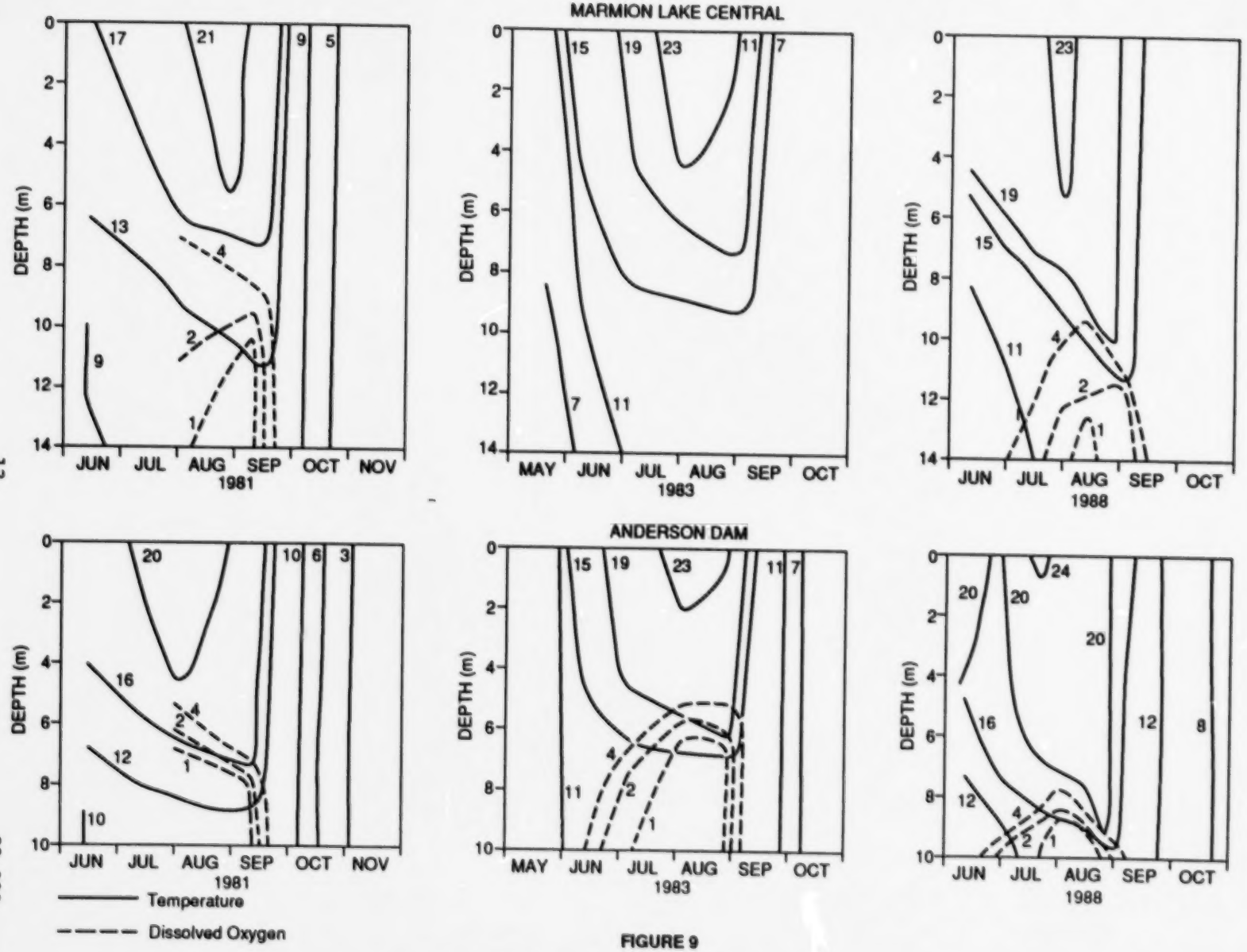

FIGURE 9

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES
OF MARMION LAKE CENTRAL AND ANDERSON DAM - 1981, 82 AND 88

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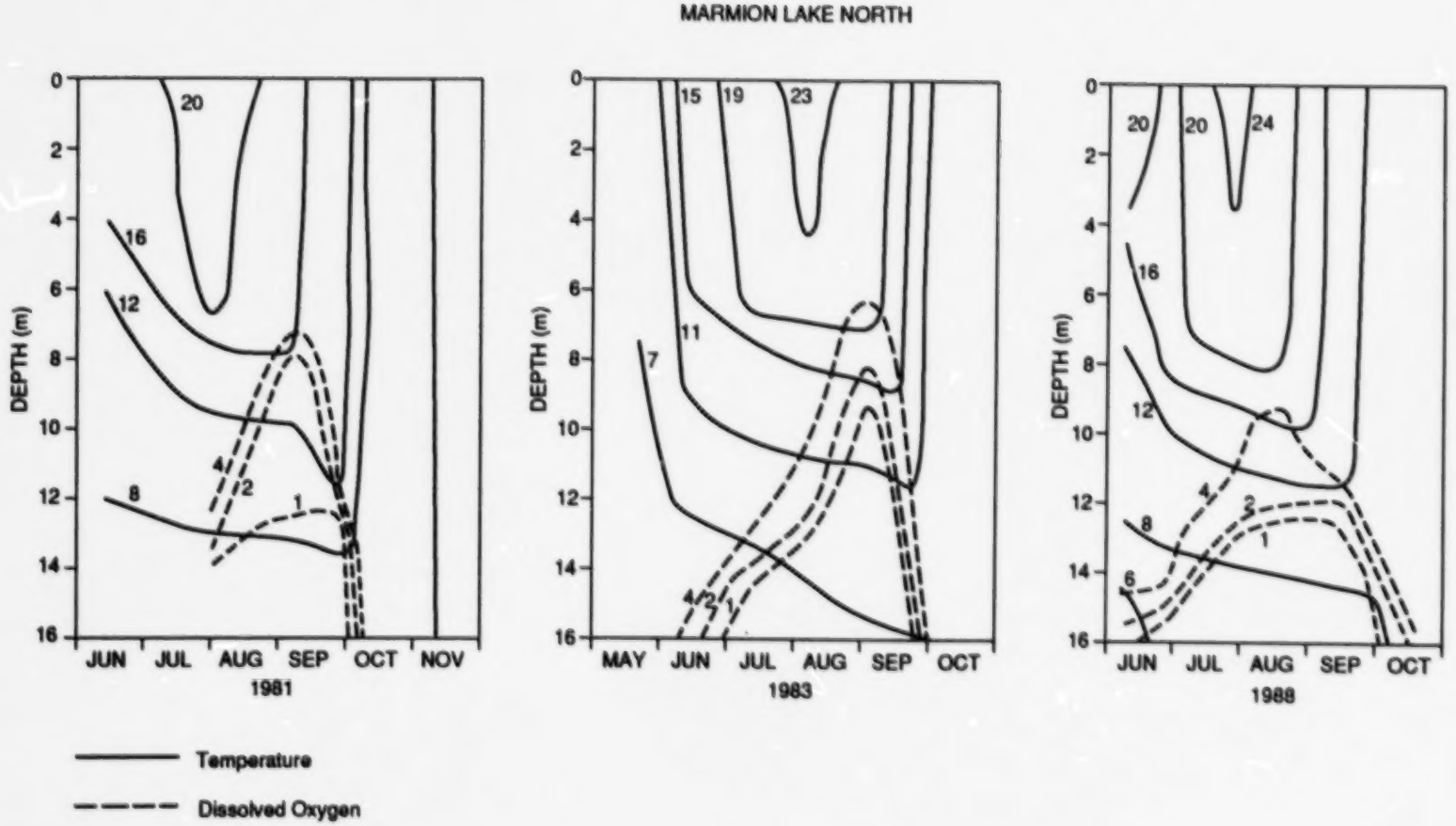

FIGURE 10

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES OF MARMION LAKE NORTH - 1981, 82 AND 88

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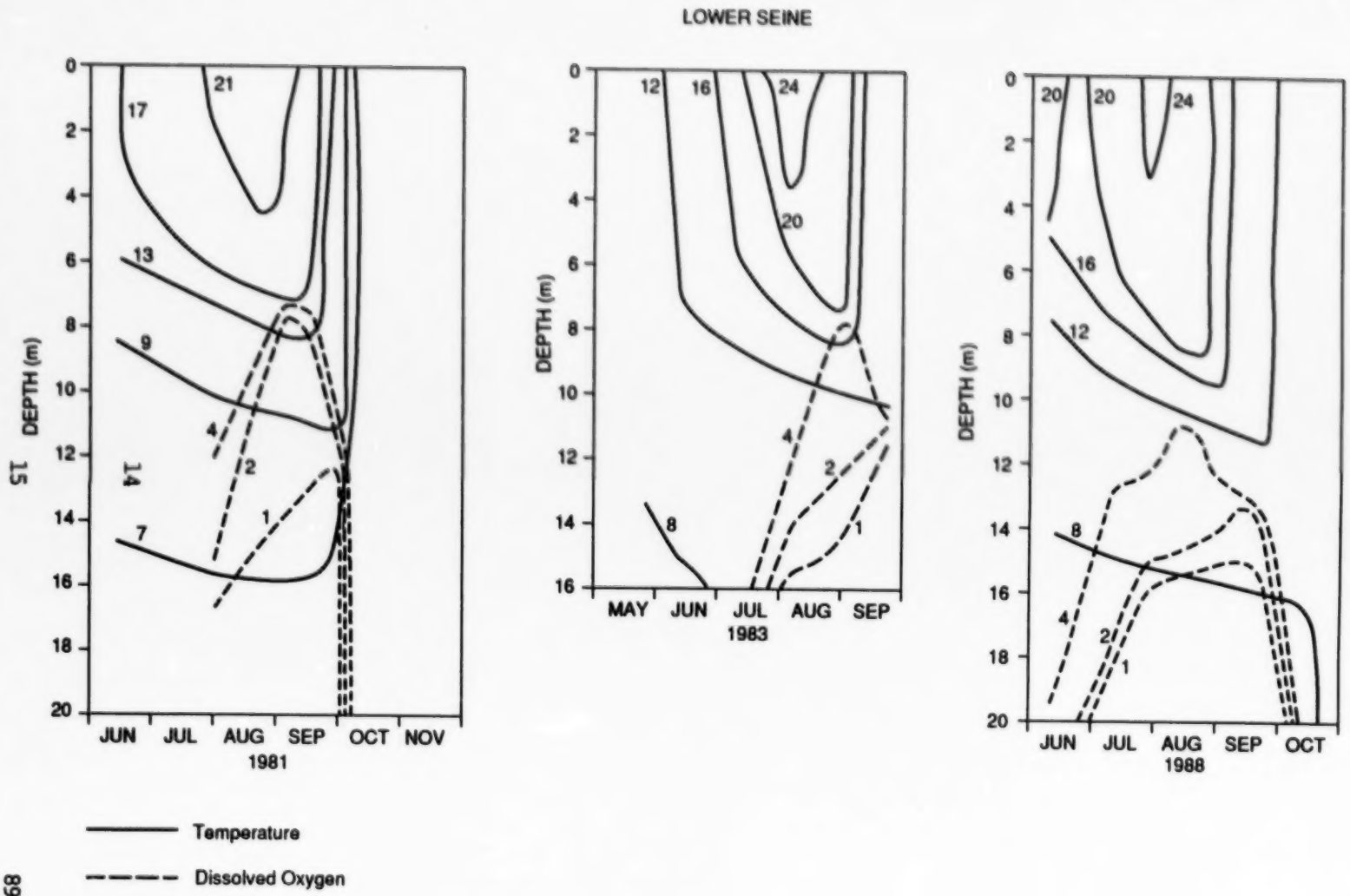

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FIGURE 11

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES OF LOWER SEINE -- 1981, 82 AND 88

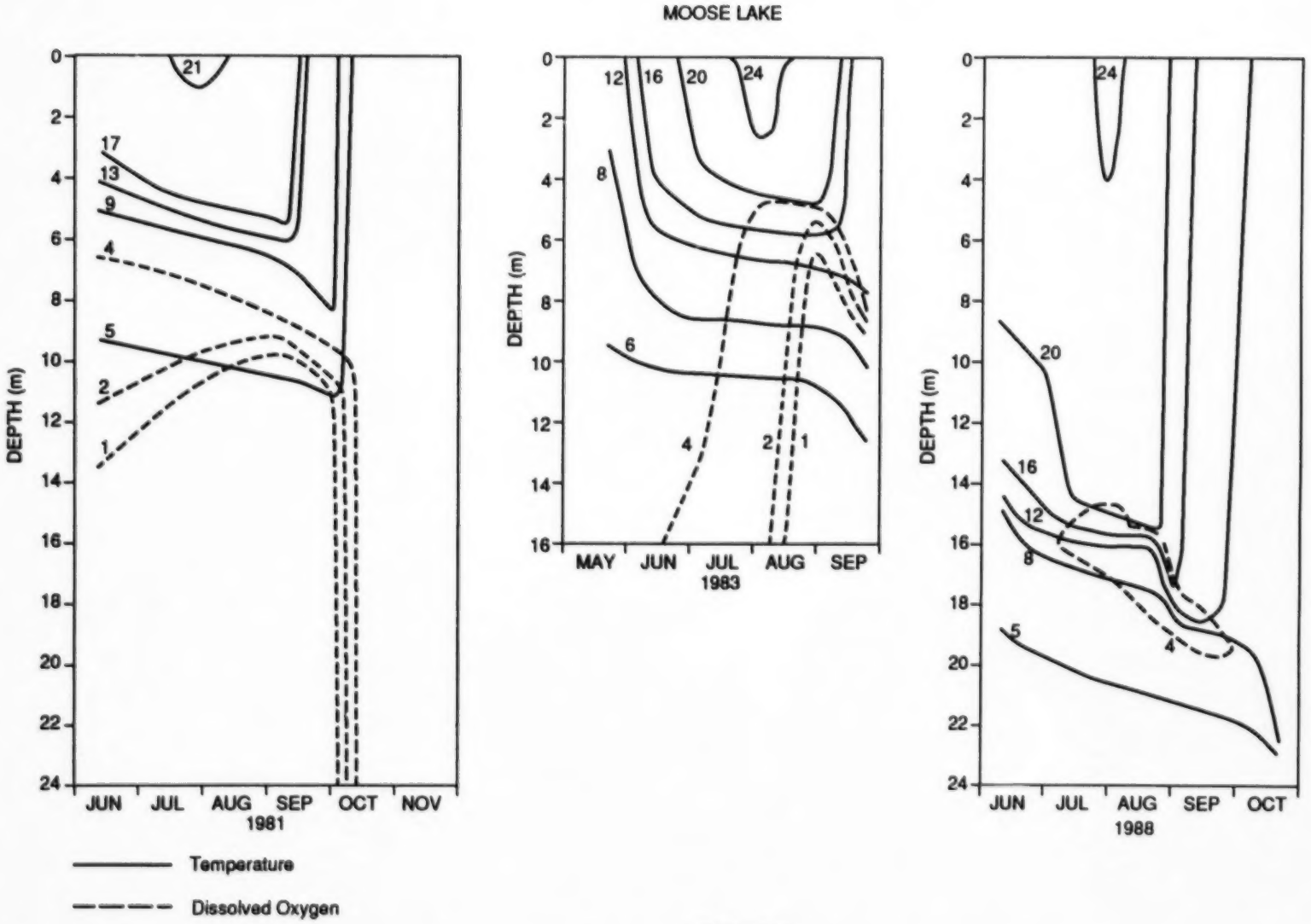

FIGURE 12

TEMPERATURE (°C) AND DISSOLVED OXYGEN (ppm) PROFILES OF MOOSE LAKE -- 1981, 82 AND 88

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The temperature profiles of Snow Lake tended to be much more erratic than those taken in 1981 and 1983 (Figure 6). The primary reason for the inconsistent nature of the profiles is the variable operation of the station (i.e. pumps running and producing heat, pumps running and not producing heat, and pumps not running). The erratic nature of the profiles was less apparent in Icy and Abie Lakes (Figures 6 and 7) and absent from the Marmion Lake locations (Figures 8-10). Temperatures in Marmion Lake during station operation were not substantially different from those when the station was not operating or relative to those prior to station operation.

In Moose Lake (Figure 12), the 1988 profiles were substantially different than those from 1981 and 1983. The epilimnion was substantially more expansive in 1988 than prior to pump operation. The maximum depth of the profiles from Moose Lake reflects the length of the cable on the meter rather than the actual depth of the lake.

The depth of the thermocline in each of the study basins is illustrated in Figures 13 to 15. The thermocline, for purposes of this comparison was defined as the shallowest depth at which the temperature dropped by approximately 2°C. When more than one profile was taken during a month, the average depth was illustrated in the figures. Also, for this comparison, when the hypolimnion was displaced by the epilimnion, the depth of the thermocline was illustrated at 1 m below the maximum depth (this is noted by an * in the figures). In 1981 and 1983, the depth of the thermocline in Snow, Icy and Abie Lakes tended to be similar to that of Slush Lake through the summer period. After operation of the station (1986 and 1988), the depth of the thermocline of the first three lakes of the cooling circuit tended to be slightly deeper than that of Slush Lake. It should be noted however that the depth of the thermocline of all of the basins, including Slush Lake, tended to be deeper in 1986 and 1988, particularly during August and September (Figures 13 to 15).

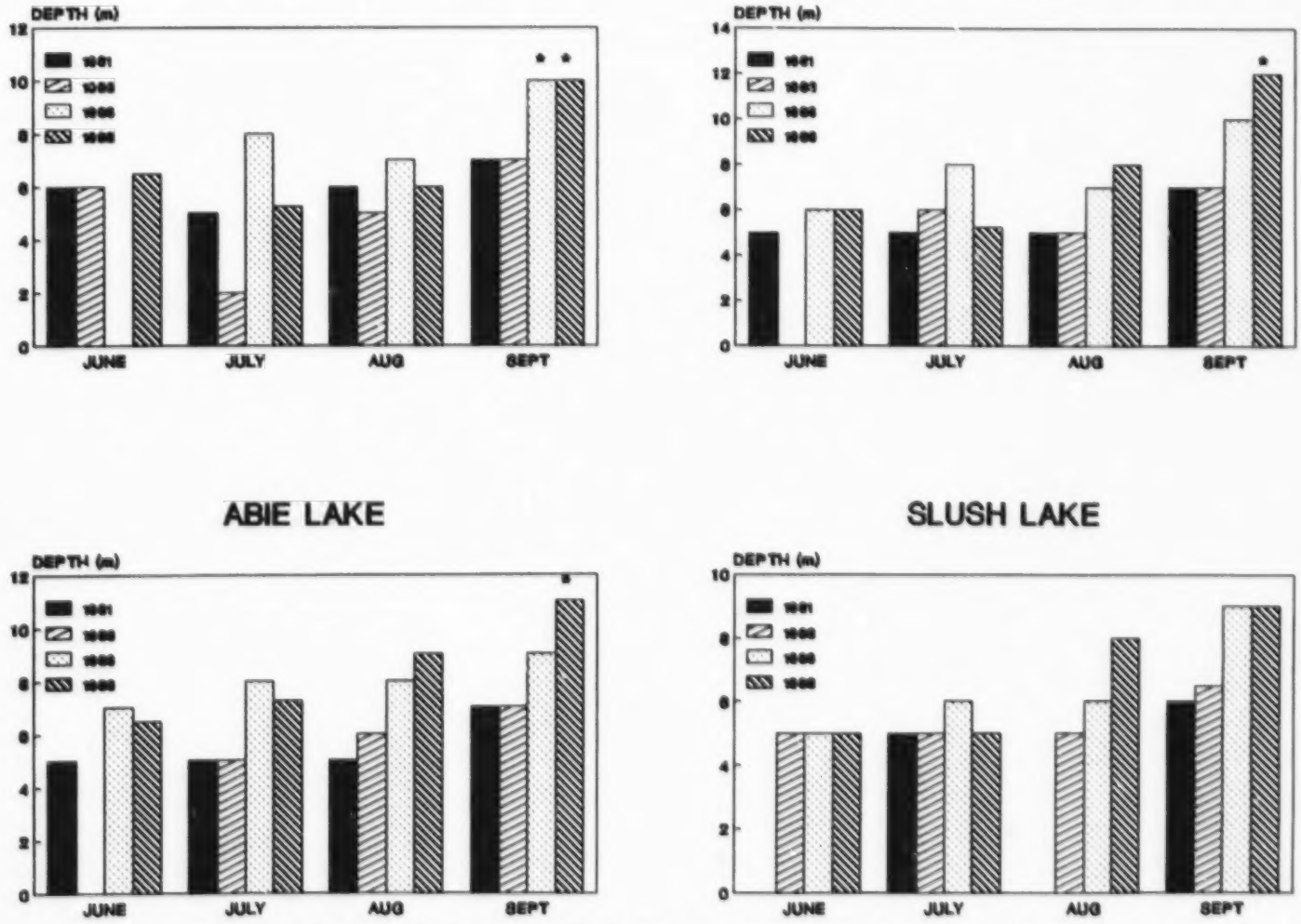
In Moose Lake, the depth of the thermocline increased substantially after the station began operation (Figure 15). The depth of the thermocline increased from approximately 5 m in 1981 and 1983 to 15 m in 1986 and 1988. One would expect that the thermocline of Moose Lake in the absence of water removal would behave in a similar fashion to that of Lower Seine which has similar morphological characteristics. The depth of the thermocline in Lower Seine increased from a depth of 5-6 m in June to 6-10 m in August (Figure 15). Thus the depth of the thermocline in Moose Lake was lowered by 9-10 m in June and by 5-9 m in August as a result of station operation.

A comparison of the temperature profiles of Snow, Icy, Abie and Slush Lakes in 1988 when the station was and was not operating is presented in Figures 16 and 17. In June, (Figure 16) the near surface temperatures of each of the lakes were similar while the station was not operating. However, while the station was operating the near surface temperatures in Abie, Icy and Snow Lakes exceeded those in Slush Lake by approximately 1, 2 and 4°C. In addition the thermocline in Snow, Icy and Abie Lakes tended to be deeper and the hypolimnetic temperatures warmer than those of Slush Lake.

In the fall (Figure 17) the epilimnetic temperatures of the four lakes were again similar while the station was not operating but during operation the temperature through most of the water column of Abie, Icy and Slush Lakes exceeded that of Slush Lake by 3, 4 and 8°C, respectively. While the station was operating, a thermocline was only apparent in Slush Lake during the fall profiles, with the exception of Snow Lake where stratification was apparent as the result of the buoyant thermal plume.

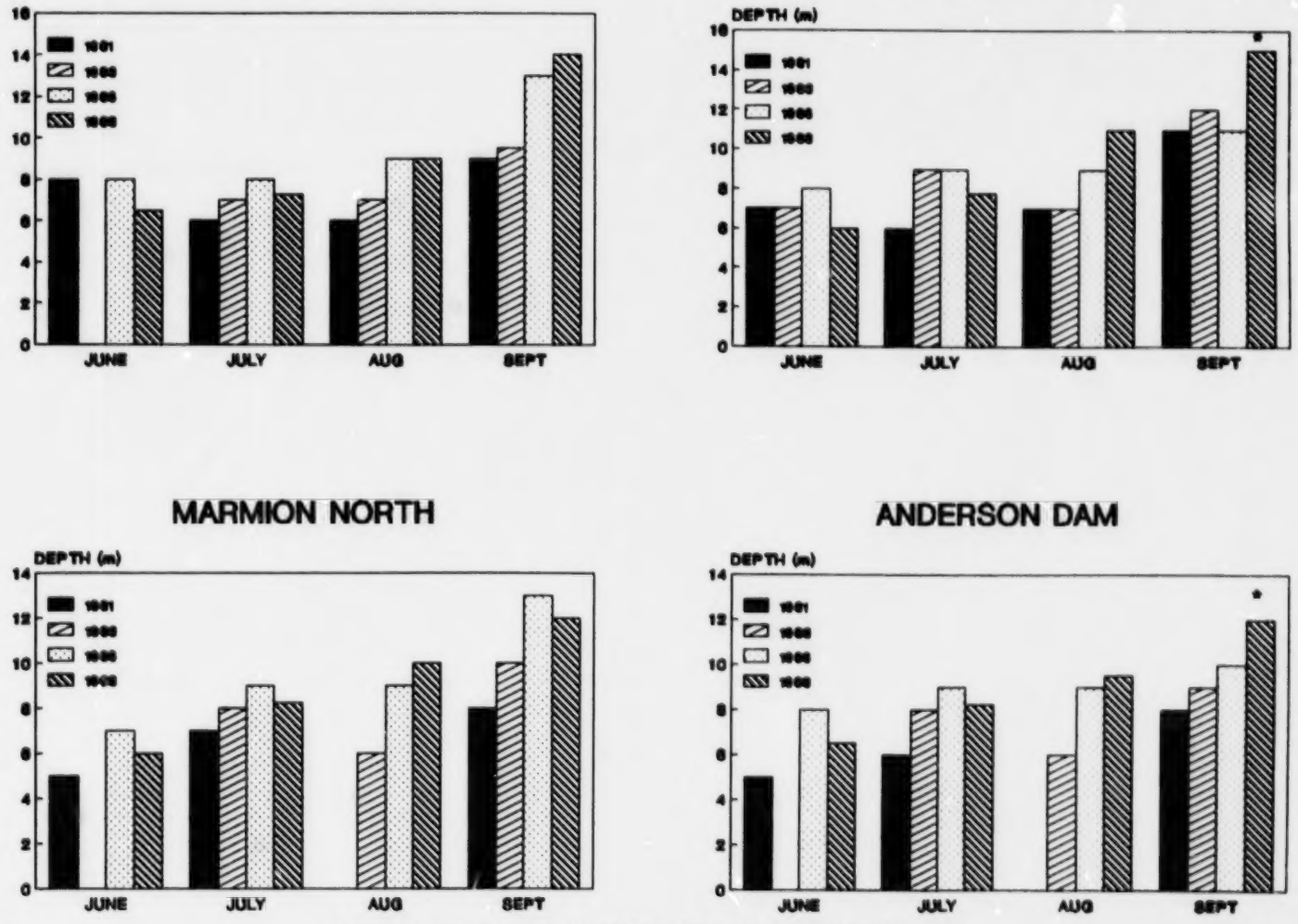
Winter profiles were taken in March 1989 (Appendix 1), however, although the pumps were operating during the visit, no heat was being produced. The profiles from the first lakes of the

FIGURE 13



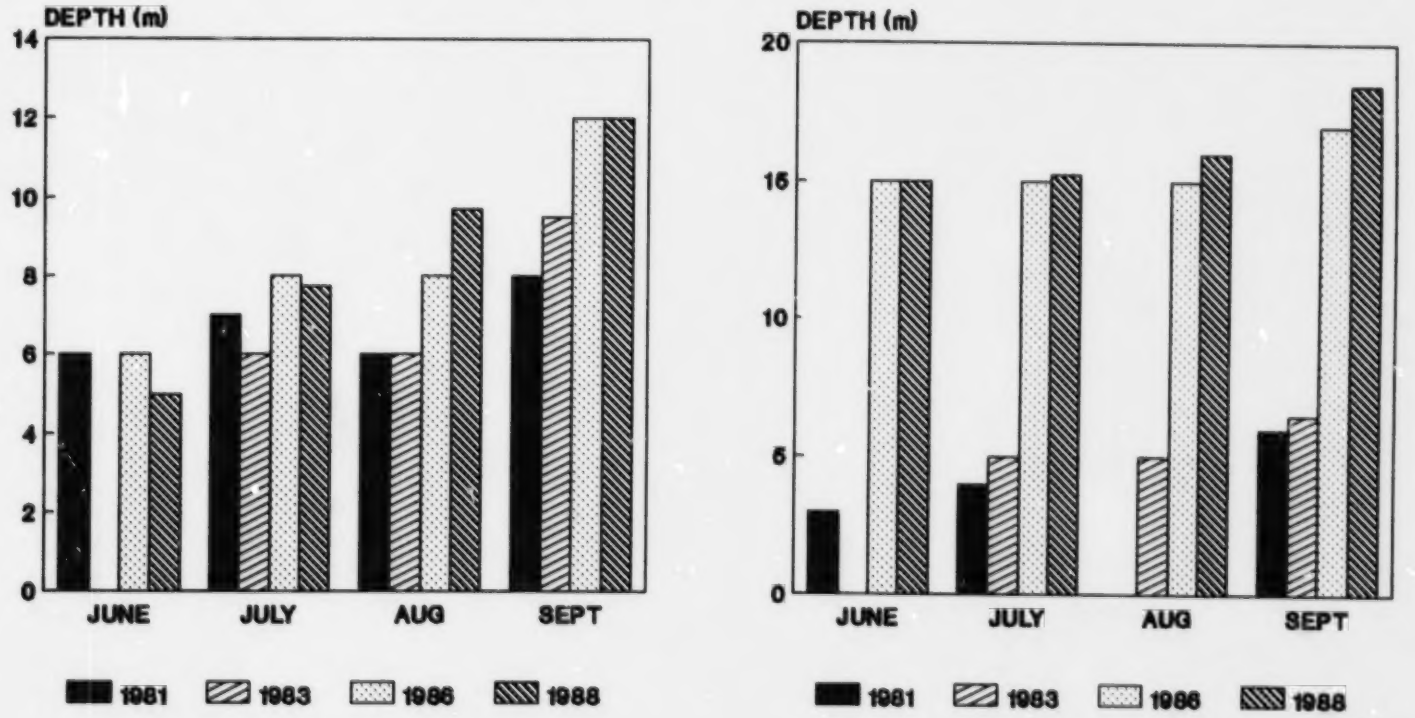
DEPTH OF THE THERMOCLINE IN SNOW, ICY, ABIE AND SLUSH LAKES

FIGURE 14

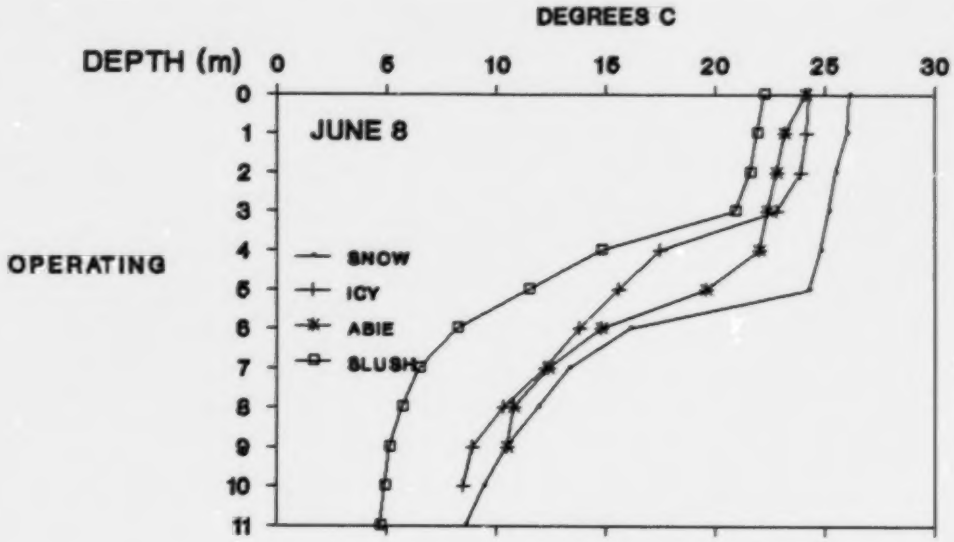


DEPTH OF THE THERMOCLINE IN MARMION LAKE

FIGURE 15



DEPTH OF THE THERMOCLINE IN LOWER SEINE BAY AND MOOSE LAKE



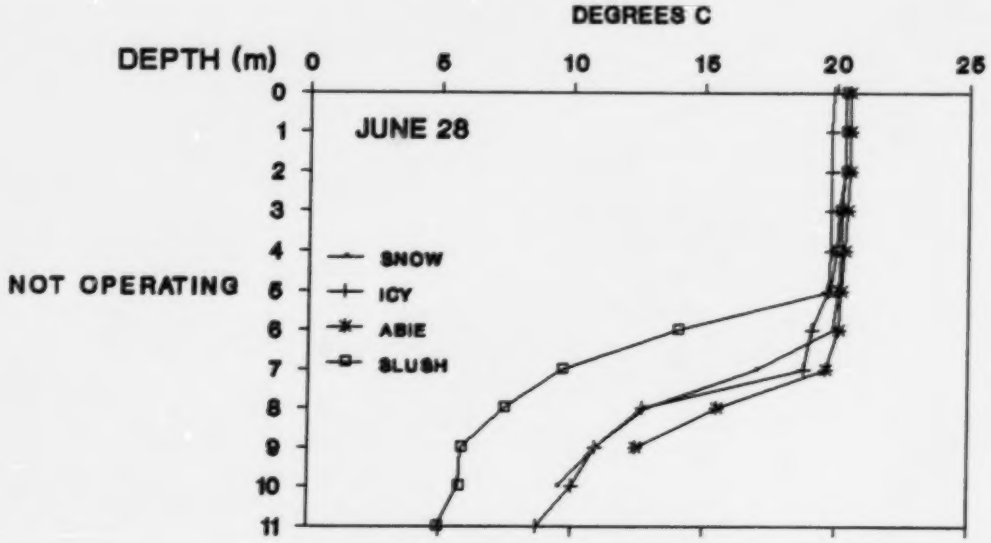
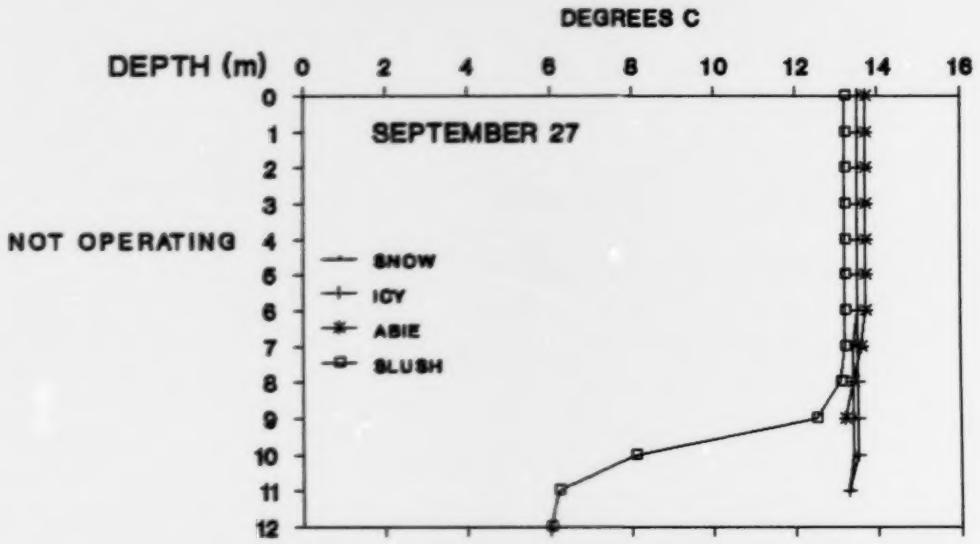


FIGURE 16

JUNE PROFILES OF SNOW, ICY, ABIE AND SLUSH LAKES 1988



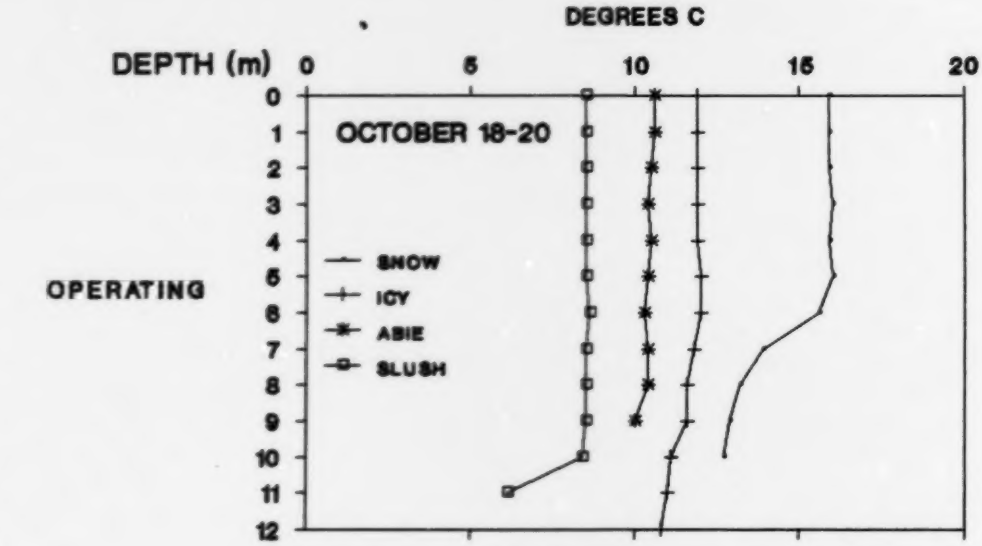


FIGURE 17
FALL PROFILES OF SNOW, ICY ABIE AND SLUSH LAKES 1988

cooling circuit were homeothermal at 1 to 2°C. The winter profiles were similar to those measured during the preoperational phase.

Winter Ice Cover

Based on casual observations prior to station operation, ice generally began to form on the study lakes in November or December and began to break up from mid-April to the beginning of May. Ice on the smaller lakes tended to clear earlier (approximately a week) than Marmion Lake. After the station began operating, Snow and Icy Lakes did not completely freeze over, although some shore ice formed on Icy Lake. Abie Lake would freeze over almost completely at the beginning of winter but gradually a channel of open water through Abie Lake into Marmion Lake would form and widen as the winter progressed leaving only the two bays of Abie Lake, outside the main current, frozen by the end of the winter.

When the station shut down and the pumps were shut off during the winter, a thin cover of ice would form over the open areas relatively quickly.

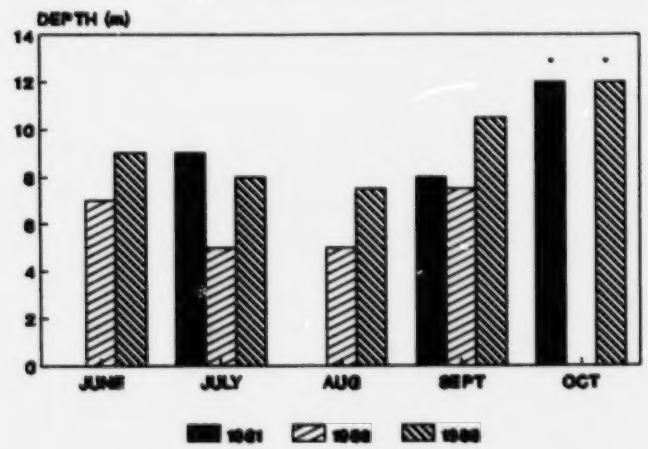
Oxygen

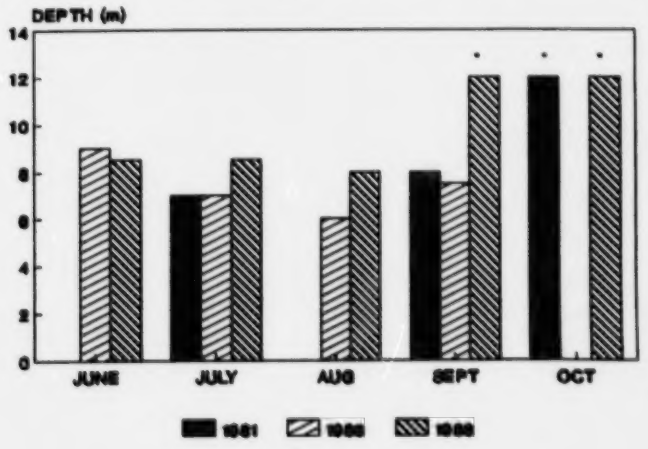
Oxygen profiles from 1988 and March 1989 are listed in Appendix 1 and areas of reduced oxygen concentration are compared to those from 1981 and 1983 in Figures 6 through 12. Data from 1987 were not analyzed due to recurring equipment failure. Hypolimnetic oxygen depletion was apparent in all basins in each year except 1986. It is suspected that the oxygen meter did not function properly at low oxygen concentrations during 1986.

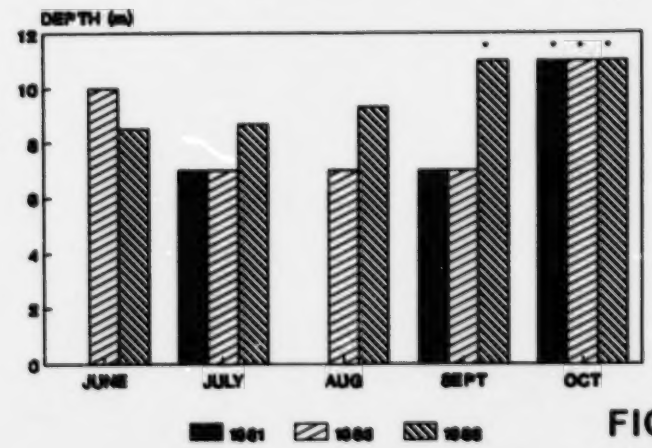
The minimum depth at which oxygen levels were below 1 ppm in 1981, 1983 and 1988 is illustrated in Figures 18 and 19. In the first three lakes in the cooling circuit the minimum depth of oxygen depletion tended to closely follow the depth of the thermocline. Much of the hypolimnion was depleted of oxygen from July until stratification disappeared in September or October. With the lowering of the thermocline during 1988 (see above), the minimum depth of oxygen depletion increased, particularly after July. Although more of the water column was oxygen rich in 1988, the extent of the hypolimnion that was oxygen depleted actually increased. A similar trend was also apparent at some of the Marmion Lake (Marmion South and Central and Anderson Dam) locations in 1988 but the increased depth of oxygen depletion occurred later in the summer (August or September) (Figure 19).

In Moose Lake in 1988 oxygen depletion was apparent at the thermocline with levels increasing in the top few meters of the hypolimnion (Figure 12). This indicates high heterotrophic activity at the thermocline.

In Snow and Icy Lakes the initial stages of winter oxygen depletion were apparent in the October measurements during 1988 (Figure 6). This oxygen depletion was coincident with the start up of the station after a September shut down. This evidence suggests that oxygen depletion of the hypolimnions of Snow and Icy Lakes will occur during the winter whenever the operating station can maintain thermal stratification. Reduced hypolimnetic oxygen concentrations were recorded during winters of the preoperational years. Although station operation may contribute to hypolimnetic oxygen depletion when it is producing heat, it will tend to recharge the deeper strata with oxygen when the station is pumping but not producing heat such as when the station is being shut down as occurred during March, 1989 (Appendix 1). When the pumps are operating but heat is not being produced, cold oxygenated water is passed through the station and the discharge is mixed throughout the water column of Snow Lake as opposed to the heated discharge which is buoyant and spreads across the surface of the lake.







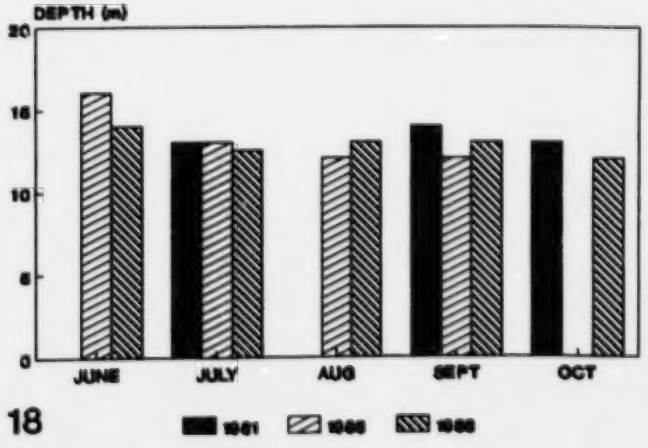
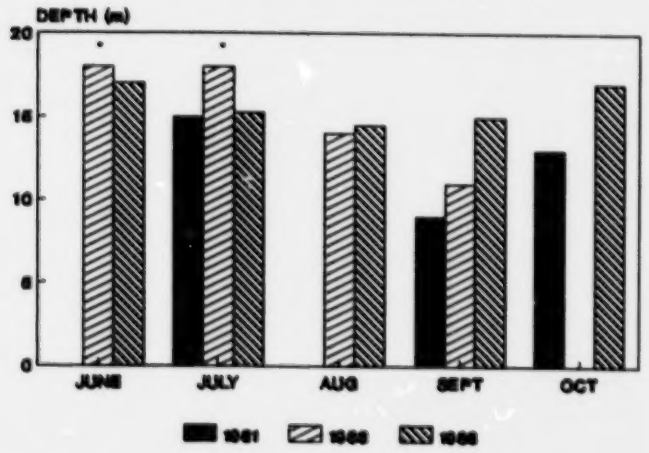
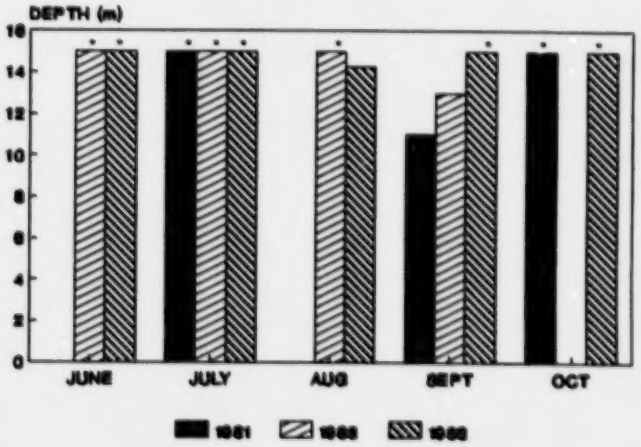
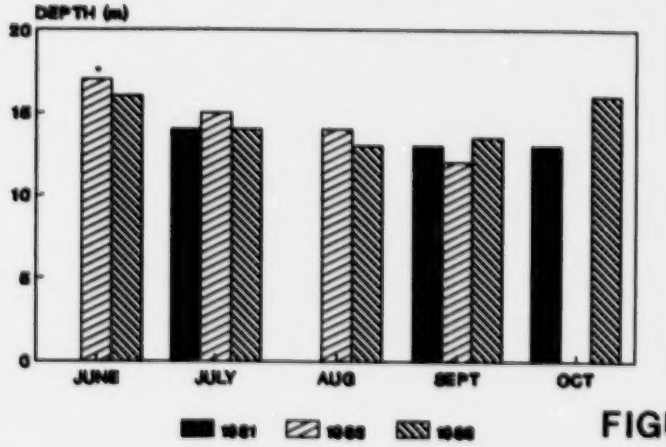


FIGURE 18

MINIMUM DEPTH OF 1 PPM OXYGEN IN SNOW, ICY, ABIE AND SLUSH







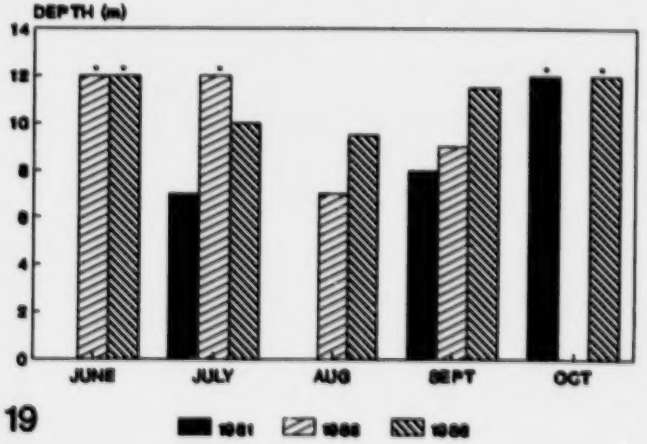


FIGURE 19

MINIMUM DEPTH OF 1 PPM OXYGEN IN MARMION LAKE

3.3 Transparency

Water transparency was measured as Secchi depth in 1981, 1983 and 1988. The mean monthly measurements are listed in Table 2. Transparency measurements taken in 1988 tended to be similar to those taken in 1981 and 1983 at most locations. The only exceptions were Icy, Abie and possibly Moose Lakes where Secchi depths tended to be shallower than similar measurements during the preoperational phase. Water clarity in Snow Lake was highest in 1981, prior to major construction activities on the lake and operation of the station.

This trend to lower Secchi depths in Icy and Abie Lakes after operation of the station is not consistent with the observed reduction in turbidity in Icy Lake and the lack of trend in Abie Lake (Haymes 1989). Similar turbidity data for Moose Lake are not available. The trend toward lower clarity in Moose Lake is likely the result of the breaching of Anderson Dam. With the station operating, water from Anderson Dam, where the lowest Secchi depths were recorded, is drawn into Moose Lake.

3.4 Currents and Flows

Currents were measured across the narrowest section of the connecting channels during 1982, 84, 85, 86 and 87 and flows were calculated according to the procedures outlined in Dodge et al. (1980). Spring (April and May) flows and currents are listed in Table 3. Flows and currents in the channel between Ski and Icy Lakes which are not influenced by the station discharge were quite variable depending on the timing and magnitude of the spring freshet.

Prior to operation of the generating station pumps, currents and flows in the connecting channels of the cooling circuit were also variable and dependent on the timing and extent of the spring freshet. However, while the pumps are operating, flows and average currents are dependent almost entirely on the volume of water being pumped by the station. Consequently, flows and currents are considerably higher and less variable in the connecting channels.

3.5 Substrates and Sedimentation

Substrates of the study lakes were mapped during 1981 (Haymes 1983). Generally, substrates in each of the study basins consisted of rocky shorelines changing to soft unconsolidated sediments with increasing depth. Extensive areas of submerged timber were common in Marmion and Moose Lakes. Exceptions included the dumped spoils area in Marmion Lake to the east of Anderson Dam, a sand-gravel-cobble beach at Anderson Dam and other small sandy beaches interspersed through the cooling circuit.

Although studies were not conducted to examine changes in the sediment erosion and deposition patterns in the cooling circuit as a result of station operation, one would expect that establishment of the cooling circuit and its associated currents would result in some changes in erosion and deposition patterns. Casual observations during other aspects of the Atikokan study did indicate that sediment deposition areas were established downstream of some of the connecting channels where currents began to dissipate. These deposition areas were characterized by luxuriant growths of macrophytes (Kwik and Dunstall 1989). The connecting channels where currents were relatively high were generally silt-free.

TABLE 2

MEAN MONTHLY SECCHI DEPTH (m) 1981, 1983 AND 1988

		May	June	July	Aug	Sept	Oct	Mean *
Snow Lake	1981	2.8	3.8	-	4.4	4.0	2.1	3.5
	1983	1.6	2.5	2.5	2.1	1.7	1.9	1.9
	1988	-	-	-	3.0	2.4	2.5	2.6
Icy Lake	1981	3.0	4.2	-	6.2	3.6	2.0	3.9
	1983	2.5	2.9	5.1	5.0	3.2	2.1	3.4
	1988	-	-	-	3.8	2.0	2.9	2.9
Abie Lake	1981	-	4.1	-	4.6	3.8	2.0	3.5
	1983	2.9	5.0	5.1	5.0	3.8	2.0	3.6
	1988	-	-	-	3.2	2.5	2.8	2.8
Slush Lake	1981	-	-	-	4.1	4.1	3.7	4.0
	1983	3.0	3.0	6.8	6.8	4.9	2.9	4.9
	1988	-	-	-	4.1	4.0	4.3	4.1
Marmion South	1981	4.0	4.4	3.6	3.7	3.8	2.9	3.5
	1983	3.0	4.2	5.6	4.0	4.2	2.0	3.4
	1988	-	-	-	4.0	3.0	2.7	3.2
Marmion Central	1981	3.3	4.0	3.6	4.1	3.0	2.0	3.0
	1983	2.5	3.5	5.0	6.5	3.8	-	-
	1988	-	-	-	3.7	-	3.0	-
Marmion North	1981	-	3.6	4.7	4.0	2.8	3.2	3.3
	1983	2.7	4.3	6.2	6.0	4.0	2.2	4.1
	1988	-	-	-	3.6	3.8	2.9	3.4
Anderson Dam	1981	3.0	3.2	2.7	3.7	1.2	1.2	2.0
	1983	1.9	3.0	2.9	1.5	1.8	0.9	1.4
	1988	-	-	-	2.2	1.6	1.9	1.9
Lower Seine	1981	3.5	5.2	3.2	3.8	4.2	3.0	3.7
	1983	3.0	4.5	3.5	3.8	3.3	-	-
	1988	-	-	-	4.5	4.0	3.5	4.0
Moose Lake	1981	-	-	-	4.0	3.2	2.9	3.4
	1983	3.2	3.5	4.5	3.5	3.4	-	-
	1988	-	-	-	3.1	2.2	2.9	2.7

* mean of August, September and October

TABLE 3

SPRING FLOWS AND CURRENTS IN THE CONNECTING CHANNELS

		Spring Flow (m3/s)		Current (m/s)	
		Mean	Range	Mean	Range
Snow/Icy	1982a	0.06	0.04-0.09	0.13	0.00-0.23
	1984a			0.06	0.04-0.08
	1984b			1.06	0.75-1.70
	1986b	7.17	5.8-8.2	0.66	0.30-0.90
	1987b	6.23	-	0.77	0.20-1.26
Ski/Icy	1984			1.20	
	1985	low		slight	-
	1986	0.77	0.6-1.0	0.71	0.35-1.00
Icy/Abie	1982a	1.36	1.20-1.53	0.05	0.00-0.40
	1984a			0.16	0.12-0.23
	1985b	5.13	-	0.20	0.15-0.26
	1986b	5.63	4.8-6.3	0.20	0.06-0.30
	1987b	6.80	-	0.34	0.02-0.26
Abie/Marmion	1982a	0.73	0.63-0.80	0.05	0.00-0.10
	1984a			0.12	0.09-0.16
	1985b	4.27	-	0.26	0.12-0.35
	1986b	4.47	3.9-4.9	0.12	0.00-0.23
Marmion/Moose	1984a			0.05	-
	1986b	8.40	8.0-8.8	0.14	0.03-0.19

a-pumps not operating
b-pumps operating

4.0 DISCUSSION

A workshop held in 1984, which included representatives from Ontario Hydro, the Ontario Ministries of Natural Resources and Environment as well as other agencies which could be affected by the operation of Atikokan TGS, formulated a series of hypotheses of effect related to the construction and operation of Atikokan TGS (Greig et al. 1984). These hypotheses originate in an action or characteristic of the station through a series of intermediate steps to an eventual impact on a valued ecosystem component.

This discussion will focus on the hypotheses and specifically on those steps (linkages) which relate to physical components of the environment which were discussed in this report.

Hypothesis No. 4

"The construction of dams, weirs and channels in the cooling circuit lakes will lead to:

a) changes in the species composition, distribution and abundance of fish with consequent changes in fishing effort and the abundance of fish-eating wildlife, and

b) changes in the distribution of waterfowl, shorebirds and furbearers."

Link No. 2

"Construction of dams, weirs and channels has changed current patterns and substrates."

A dam was constructed at the northeast end of Marmion Lake near the Marmion North sampling site which substantially reduced the exchange of water between Marmion Lake and the Seine River Basin. Some exchange of water still occurs at the Spillway Dam but the direction of flow is from Marmion Lake to the Seine River most of the time.

A weir was constructed at the outflow of Snow Lake which has stabilized the water level of Snow Lake.

A new channel was created between Marmion and Moose Lakes by breaching the Anderson Dam. In addition, channel improvements (widening and/or deepening) were performed at the outflows of Snow Lake into Icy Lake, Icy Lake into Abie Lake and Abie Lake into Marmion Lake. These resulted in slight decreases in the depths of Snow and Icy Lakes.

Operation of the station has resulted in increased and consistent flows and currents in the connecting channels. These currents and flows likely exceed those which would normally have been experienced during the spring freshet prior to station operation.

Changes in the current regime of the cooling circuit have likely caused changes in sediment erosion and deposition patterns. Indirect evidence suggests that deposition of sediments has increased immediately downstream of the connecting channels where currents begin to dissipate.

As part of the construction program rubble and gravel substrates were placed in the outflows of Snow, Icy, Abie and Marmion Lakes.

Hypothesis No. 5

"Discharges of heated water from the Atikokan Generating Station will lead to physical changes resulting in:

a) changes in the distribution, composition, abundance, productivity and harvest of fish

b) changes in fishing effort

c) increase in accidents

d) changes in waterfowl

e) destruction of vegetation."

Link No. 1

"Discharge of water from Atikokan TGS will lead to sinking plume of oxygen-rich water in Snow, Icy and Abie Lakes in the winter when water temperatures are less than 4°C."

During the winter the bottom strata of each of the study basins tended to be oxygen poor during the preoperational years. Winter discharge plumes tend to impinge upon the bottom when they reach 4°C (Haymes and Dunstall 1989). Since the water used to cool the condensers is drawn from the 10 m depth in Moose Lake, the discharge should be well oxygenated in the winter. The extent to which the thermal plume would recharge bottom waters in Snow Lake should be related to the length of time for the temperature of the discharge to reach 4°C after leaving the station. Based on temperature records from the Snow Lake outflow (Lawler pers. comm) the temperature of the discharge still exceeds 4°C at the Snow Lake outflow. Consequently, oxygen depletion of bottom waters will likely still occur in Snow Lake but not necessarily in Icy and Abie Lakes.

The only oxygen profiles during the winter were taken in March, 1989 when the station, while not producing heat, was pumping water through the condensers. The profiles indicated that the bottom waters of Snow and Icy Lakes were well oxygenated as would be expected as the temperature of the discharge was about 2°C. Consequently, although oxygen depletion of bottom waters may occur in at least Snow Lake when the station is discharging heated water, the oxygen levels in bottom waters would be replenished when the station shuts down as the pumps are rarely shut off during short shut downs. In addition, as Snow and Icy Lakes are ice-free while the station is operating, wind-induced mixing may result in oxygenation of the bottom strata.

Link 2 (also Hypothesis No.7 Link No. 11)

"Discharge of water from the Atikokan TGS will lead to changing water currents at the outfall, and in the connecting channels at the outlets of Snow, Icy and Abie Lakes"

Currents in the connecting channels have increased (see Hypothesis No. 4, Link No.2).

Link No. 3 (also Hypothesis No. 7, Link No. 9)

"Discharge of heated water from Atikokan TGS will lead to changing water temperatures in the first four cooling water lakes: Snow, Icy, Abie and Marmion."

A comparison of the temperature profiles of Snow, Icy, Abie and Slush Lakes in 1988 when the

station was and was not operating is presented in Figures 16 and 17. In June, (Figure 16) the near surface temperatures of each of the lakes were similar while the station was not operating. However, while the station was operating, the near surface temperatures in Abie, Icy and Snow Lakes exceeded those in Slush Lake by approximately 1, 2 and 4°C. In addition the thermocline in Snow, Icy and Abie Lakes tended to be deeper and the hypolimnetic temperatures warmer than those of Slush Lake. Temperatures in Marmion Lake during station operation were not substantially different from those when the station was not operating or relative to those prior to station operation.

Link No. 4 (also Hypothesis No. 7, Link No. 12)

"Currents in the connecting channels and outfall will cause the resuspension of sediments in Snow and Icy Lakes."

The currents generated in the connecting channels by the discharge have likely changed the sediment erosion and deposition patterns in the cooling circuit. Indirect evidence suggests that net sediment deposition occurs immediately downstream of the connecting channels where currents dissipate. Additionally, in the connecting channels where currents are highest, particularly at the outflow of Snow Lake, substrates are maintained relatively silt free. There was no evidence of increased shoreline erosion.

Link No. 11

"Changing water temperatures in the cooling water lakes will lead to decreased ice thickness."

Snow and Icy Lakes remain relatively ice free in the winter when the station is operating. Abie Lake and Marmion Lake in the vicinity of the Abie Lake outflow, although almost completely frozen over at the beginning of winter, gradually become more open as the winter progresses. Observations of the ice at the edge of the open water in Abie Lake and at the outflow of Abie Lake indicated that it was quite thick despite its gradual erosion. Thus the ice appears to erode from the edge rather from below.

When the station shuts down during the winter a thin layer of ice forms over the open water areas relatively quickly.

Link No. 12

"Decreased ice thickness will lead to increased winter accidents"

Although we are unaware of any accidents associated with the ice conditions caused by the station, the potential for accidents is assumed to be relatively high. The outflow of Abie Lake has become a relatively popular fishing spot for local anglers. Fishermen, using snowmobiles for access, fish at the edge of the ice at the open water channel where they can use rod and reel rather than regular ice fishing techniques. Similarly, fishing from boats in the open water areas is also employed.

The formation of a thin layer of ice on the open lakes in the middle of winter when the station is not operating should also be considered a hazard, particularly for those not familiar with the area.

Link No. 15

"Changing water temperature in the cooling water lakes will lead to fog and rime ice formation."

Under certain weather conditions, some fog has been observed on Snow Lake. This fog has led to limited rime ice formation on vegetation at the periphery of the lake.

Link No. 18

"Changing water temperature will result in a lower thermocline in the cooling water lakes".

In 1988 the depth of the thermocline in all the study basins, including those not directly influenced by station operation, tended to be greater than during the preoperational period. However, the depth of the thermocline in Snow, Icy and Abie Lakes, although similar to that of Slush Lake during the preoperational period, tended to be greater than that of Slush Lake in 1988.

Hypothesis No. 6

"Withdrawal of cooling water from Moose Lake will lead to reductions in Moose Lake fish populations"

Link No. 2

"The intake of water from Moose Lake will lower the thermocline in Moose Lake"

Removal of water by the station has resulted in a substantially deeper thermocline in Moose Lake since the pumps became operational. The relatively stable thermocline establishes itself at a depth of approximately 15 m by June. One would expect that the thermocline of Moose Lake in the absence of water removal would behave in a similar fashion to that of Lower Seine which has similar morphometric characteristics. The depth of the thermocline in Lower Seine increases from a depth of 5-6 m in June to 6-10 m in August. Thus the depth of the thermocline in Moose Lake was lowered by 9-10 m in June and by 5-9 m in August (Figure 15).

5.0 CONCLUSIONS

1. The thermal discharge has led to increases in the temperature of surface and bottom waters in Snow, Icy and Abie Lakes. The depth of the thermocline in these lakes has also increased.

2. Snow and Icy Lakes and parts of Abie Lake and Marmion Lake (near Abie Lake) are ice free while the station is operating in the winter.

3. The thermocline of Moose Lake has lowered substantially as a result of the removal of water by the station.

4. Hypolimnetic oxygen depletion of most of the basins occurs during thermal stratification and to a lesser extent during the winter. Operation of the CCW pumps during station shutdowns in the winter replenishes oxygen concentrations of bottom waters in at least Snow Lake.

5. Water clarity in Icy and Abie Lakes has tended to decrease after station operation but this observation is not consistent with measurements of turbidity in these lakes.

6. Operation of the station has led to substantial increases in currents in the connecting channels of the cooling circuit and these currents have likely had some influence on sediment erosion and deposition patterns.

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APPENDIX 1

TEMPERATURE AND DISSOLVED OXYGEN PROFILES
ATIKOKAN 1988-1989

SNOW LAKE

DEPTH (m)	June 8		June 28		July 6		July 14		July 22		July 28		Aug 10		Aug 26		Sept 1		Sept 27		Oct 18		March 7	
0	26.1	7.7	20.3	7.9	27.7	7.6	28.2	6.8	29.2	7.6	30.6	7.2	29.1	7.2	26.6	8.7	25.9	8.5	13.5	9.3	15.9	9.4	1.8	9.5
1	26	7.7	20.3	7.9	27.7	7.6	28	6.9	29.2	7.4	30.6	7.2	29	7.2	26.6	8.6	25.9	8.4	13.5	9.3	15.9	9.4	1.8	9.6
2	25.5	7.7	20.3	7.9	27.7	7.6	27	7	29.2	7.4	30.6	7.2	28.6	7.3	26.6	8.4	25.5	8.4	13.5	9.3	15.9	9.4	1.8	9.6
3	25.2	7.7	20.2	7.9	27.5	7.5	26.7	7	29.1	7.4	30.6	7.2	24.8	7.3	26.6	8.2	25.8	8.3	13.5	9.3	16	9.4	1.9	9.6
4	24.8	7.7	20.2	7.9	25.6	7.7	26.6	7	27.6	7.3	30.6	7.1	23.8	6.8	26.4	8.2	25.8	8.3	13.5	9.3	15.9	9.2	1.9	9.7
5	24.3	7.7	20.1	7.6	21.7	8.1	26	6.8	25.5	6.6	28.6	7.4	23	5.7	26.3	8.1	25.6	8.3	13.5	9.3	16	9.1	1.9	9.8
6	16.1	9.9	19.9	7.7	20.1	7.9	20.1	7	20.5	6.7	23.3	6.8	19	0.7	26.2	8	24.7	7.7	13.5	9.3	15.6	8.9	1.9	9.7
7	13.3	9	17	5.5	18.2	5.7	18.8	5.6	16.6	2.2	18	2.9	15.4	0	25.7	7.6	24.3	7.1	13.4	9.3	13.9	6.4	1.9	9.6
8	11.9	4.3	12.8	1.2	13	0	15	0.7	14	0	15.3	0.3	12.3	0	25	4	21.3	3.1	13.4	9.3	13.2	6.3	0	9.7
9	10.4	0	10.9	0	11.2	0	12.1	0	11.6	0	12.3	0	10.7	0	18.9	0.6	15.8	0.6	13.4	9.3	12.9	5.7	2.1	9.7
10	9.4	0	9.5	0	10.3	0	10.5	0	10.2	0	10.8	0	10.7	0	14.8	0.7	13.5	0.7	13.4	9.3	12.7	1.9	2.3	9.6
11	8.6	0									10.2	0			12.6	0.8	11.1	0.7	13.3	9.3				
12															11.3	0.8								

ICY LAKE

DEPTH (m)	June 10		June 28		July 6		July 14		July 22		July 27		Aug 10		Aug 24		Aug 31		Sept 27		Oct 5		Oct 20		March 8	
0	24.3	7.9	19.9	7.9	26.6	7.7	26.8	7.3	27.5	7.6	27.3	7.6	26	7.5	23.5	7.5	21.1	8.5	13.5	9	15.6	9.9	11.9	9.1	2.4	9.5
1	24.2	7.9	19.8	7.9	26.6	7.7	24.2	7.3	26.9	7.6	27.3	7.7	25.9	7.4	23.5	7.5	21.1	8.5	13.5	9	14	9.5	11.9	9.1	2.5	9.4
2	23.9	8	19.8	7.9	26.5	7.6	24	7.2	25.6	7.6	27.1	7.8	25.8	7.4	23.5	7.5	21	8.5	13.5	9	11.9	9.8	11.9	9.1	2.4	9.3
3	22.8	8.2	19.8	7.9	25.6	7.7	23.8	7.2	25.3	7.6	26.5	7.7	25.1	7.4	23.4	7.4	21	7.9	13.5	9	11.3	9.6	11.9	9.1	2.5	9.3
4	17.5	9	19.8	7.9	23.3	8.1	23.5	7.4	24.6	7.5	25.9	7.8	24.4	7.4	23.3	7.3	20.6	7.7	13.5	9	11.3	9.5	11.9	9.1	2.5	9.2
5	15.6	9.4	19.7	7.6	21.7	8.1	22.6	7.5	23.6	7.1	25	7.8	24	6.9	23.1	6.7	20.5	7.6	13.5	9	11.2	9.4	12	9.1	2.6	9.2
6	13.8	6.7	19.1	7	20.7	8.1	21	7.2	21.7	6.9	22.1	7.6	23.3	6	22	6.1	20.5	7.5	13.5	6.9	11.2	9.4	12	8.8	2.7	9
7	12.2	3.6	18.8	6.4	18.6	6.4	18.9	5.8	17.2	2.9	18.1	2.4	19.4	0	21	2.8	20.2	7.5	13.5	8.9	11.1	9.4	11.8	8.7	3	8
8	10.3	0	12.7	1.1	15	2.4	15.1	1.9	13.3	0.4	15.1	0.7	15.9	0	17.8	0.2	18.7	4.7	13.5	8.9	11	9.3	11.6	8.4		
9	8.9	0	10.9	0.8	12.2	0.2	12.3	0	11.5	0	13.5	0	12.5	0	13.7	0.3	14.6	1	13.5	8.8	10.9	9.3	11.6	7.8		
10	8.5	0	10	0.8	10.3	0	10.6	0	10.5	0	12.2	0	11.3	0	11.4	0.4	11.6	1	13.5	8.6	10.8	8.9	11.1	4.8		
11			8.7	0.6	9.5	0	9.7	0	10.1	0	11.1	0	10.1	0	10.4	0.2	10.6	0.9	13.3	7.6	10.2	8.6	11	4		
12											10.1	0											10.8	1.3		

ABIE LAKE

DEPTH (m)	June 10		June 28		July 6		July 14		July 22		July 27		Aug 10		Aug 24		Aug 31		Sept 27		Oct 5		Oct 20	
0	24.1	8.2	20.5	8	26.3	7.9	24.2	7.9	25.7	7.8	27.4	8.1	25.2	7.7	22.7	7.9	20.6	8.6	13.7	9	11.1	9.8	10.6	9.3
1	23.2	8.1	20.5	8	26.3	7.9	23.9	7.5	25.5	7.8	26.8	8.1	25.1	7.7	22.4	7.9	20.3	8.6	13.7	9	11.1	9.8	10.6	9.2
2	22.6	8	20.5	8	25.2	8	23.1	7.4	24.3	7.7	25.8	7.9	24.1	7.7	22.1	7.6	20.1	8.4	13.7	9	11.1	9.8	10.5	9.1
3	22.4	8	20.4	8	24.3	7.9	22.8	7.4	23.8	7.6	25.3	7.8	23.8	7.4	22	7.5	19.5	8.4	13.7	9	10.9	9.7	10.4	9.1
4	22	8	20.3	8	23.9	7.9	22.6	7.3	23.3	7.5	24.9	7.7	23.6	7.4	21.8	7.5	19.4	8.3	13.7	9	10.9	9.7	10.5	9.1
5	19.6	8.3	20.2	7.9	22.8	7.9	22.4	7.2	23.2	7.3	24.4	7.6	23.5	7.2	21.7	7.4	19.4	7.9	13.7	9	10.8	9.6	10.4	9.1
6	14.8	7.3	20.1	7.8	21.7	7.7	22.3	7.1	22.2	6.9	23.1	7.4	23.4	7.2	21.4	7.2	19.2	8	13.7	9	10.6	9.6	10.3	9.1
7	12.4	4.4	19.6	7.6	18.9	6.6	21.6	6.5	18.8	4.8	21	6.7	21.7	4.2	21.3	7.2	19.2	7.9	13.6	9	10.6	9.6	10.4	9.1
8	10.8	0.8	15.5	3.5	16.7	3.7	16.6	2.6	16.8	1.9	16	0.3	17.4	0	20.3	4.7	19	7.4	13.4	9	10.5	9.5	10.4	9.1
9	10.5	0.2	12.4	0.8	12.7	0	13.7	0	14.5	0	14.5	0	14.8	0	15.2	0.4	18.4	5.5	13.2	9	10.4	9.6	10	9.1
10																	15.5	1.2						

SLUSH LAKE

	June 8		June 28		July 6		July 22		Aug 10		Aug 26		Sept 1		Sept 27		Oct 20	
0	22.2	7.6	20.3	8.1	24.3	7.9	24.3	7.8	22.7	8	19.5	9.3	18.7	9.2	13.2	9.6	8.5	8.8
1	21.9	8	20.3	8.1	24.3	7.9	24.2	7.8	22.7	8	19.4	9.2	18.4	9.2	13.2	9.6	8.5	8.8
2	21.6	9.1	20.3	8.1	24.3	7.8	22.6	7.9	22.7	8	19.3	9.2	18.2	9.2	13.2	9.6	8.5	8.8
3	20.9	8.4	20.1	8.1	24	7.8	22.2	7.8	22.4	8	19.3	9.2	18	9.2	13.2	9.6	8.5	8.8
4	14.8	11	20	8.1	21.4	8.6	22.1	8	22.1	8	19.3	9.2	17.8	9.3	13.2	9.6	8.5	8.8
5	11.5	10.9	19.8	8.3	20.5	8.5	21.6	8.1	22	8	19.3	9.2	17.7	9.2	13.2	9.6	8.5	8.8
6	8.2	11.8	14	11.6	15.3	11.8	17.7	11.6	21.4	8.8	19.3	9.1	17.6	9.2	13.2	9.5	8.6	8.8
7	6.5	9.4	9.6	11.8	11.4	11.8	13.3	12	14.7	12.4	19.2	9.2	17.2	9.3	13.2	9.5	8.5	8.8
8	5.7	9.1	7.4	10.6	8.2	11.2	8.9	10.6	10.8	11.2	18.8	9.2	13.6	12.3	13.1	8.9	8.5	8.8
9	5.1	5.2	5.8	6.9	6.6	8.3	6.3	9.4	6.6	10.2	13.1	13	9	10.8	12.5	8.6	8.5	8.6
10	4.9	4.5	5.7	5.5	6.2	5.7	5.4	3.8	6.8	7.2	9.4	12	6.4	5.8	8.1	5.4	8.4	8.5
11	4.7	3.5	4.9	1.8	5.5	3.2	5.1	0.9	6	3.4	7.5	9.1	5.9	2.4	6.2	2.1	6.1	1.4
12					5.2	2.4	4.9	0	5.4	0.7	6.3	4.1	5.2	1.4	6	1.3		
13							4.6	0			5.4	2.6						
14							4.4	0			5.1	0.9						
15							4.4	0			4.7	0.9						
16											4.6	0.8						

MARMION SOUTH

DEPTH (m)	June 10		June 29		July 5		July 14		July 21		July 27		Aug 10		Aug 24		Sept 27		Oct 5		Oct 20		March 8	
0	21.3	8.3	19.8	7.9	22.5	8	22.5	7.5	24.1	7.7	24.4	8.1	22.5	7.8	20.7	7.9	13.7	8.8	11.8	9.4	9.3	8.9	0	10.7
1	21.2	8.4	19.8	7.9	22.5	8	22.2	7.6	23.9	7.9	24.4	8.1	22.5	7.7	20.7	7.9	13.7	8.7	11.6	9.3	9.3	8.8	0.4	10.5
2	20.9	8.4	19.7	7.9	22.5	8	22.1	7.5	23	8	24.2	8.1	22.5	7.7	20.7	7.9	13.7	8.7	11.4	9.1	9.3	8.8	1	10.3
3	19.7	8.7	19.7	7.9	22.3	8	21.8	7.6	22.8	8	23.7	8.1	22.2	7.7	20.6	7.9	13.7	8.7	11.2	9	9.3	8.8	1.3	10.1
4	18.7	8.8	19.7	7.9	21.9	8	21.7	7.5	22.5	8	23.4	8.1	22.2	7.6	20.6	7.8	13.7	8.7	11.2	9	9.3	8.8	1.4	10
5	16.1	10	19.7	7.8	19.7	8.1	21.5	7.5	21.9	8	23.1	8	21.8	7.3	20.6	7.8	13.7	8.7	11.2	9	9.3	8.8	1.5	10
6	13.1	9.8	19.6	7.8	19	7.9	21.5	7.5	21.2	7.9	22.1	7.8	21.5	7.2	20.6	7.8	13.7	8.7	11.2	9	9.3	8.8	1.6	9.9
7	11.8	9.3	18.1	7.5	17.2	7.5	20.8	7.3	20.3	7.2	19.9	7.5	21	6.8	20.5	7.6	13.7	8.7	11.2	8.9	9.3	8.8	1.7	9.7
8	10.9	9	15.8	7.4	14.7	7.2	16.3	6.8	16.2	6.1	17.4	6.8	19.1	5.1	20.2	6.3	13.7	8.7	11.2	8.9	9.3	9.8	1.7	9.8
9	9.9	8	12.5	7.4	12.9	6.9	14.7	5.2	13.5	5.1	15	5.5	16.9	4	17.4	3.2	13.7	8.7	11.2	8.8	9.3	8.8	1.7	9.6
10	9.1	7.8	11.7	6.3	12.2	6.3	12.3	5.2	12.3	4.6	14	4.6	15.2	3	15	2.2	13.7	8.7	11.2	8.8	9.2	8.8	1.8	9.2
11	8.2	6.7	11	6.3	11.1	5.8	11.6	5.2	11	4.6	12	4.7	12.2	3.1	13.2	2.8	13.7	8.6	11.2	8.7	9.2	8.8	1.8	8.9
12	7.2	6	9.7	5.5	10	5.4	10.3	4.8	9.3	4	10.3	4.1	10.3	3	10.9	3	13.6	8.6	11.1	8.7	9.2	8.8	1.9	8.5
13	6.5	5.6	8.1	4.8	8.1	4.3	8.3	3.6	8.3	3	8.8	3.2	8.8	2.1	9.1	2.1	13.2	6.8	11.1	8.7	9.2	8.8	1.9	7.8
14	5.8	5.3	7.1	3.8	6.9	3	7	2.4	7.3	1.9	7.4	1.2	7.5	0.2	8.3	1	10	1.1	10.4	5.4	9.2	8.8	2.1	7.1
15	5.4	3.8	6.4	2.6	6.6	2.2	6.4	0.8	6.8	0	6.6	0	6.7	0	7.1	0.3	7.6	0.8	9.1	3.1	9.2	8.9	2.2	6.6
16	5.3	2.1	5.8	1.4	6	1	6	0	6.3	0	6.2	0	6.2	0	6.5	0	6.6	0.9	6.9	0.5	9.2	8.8	2.3	5
17	5	0.9	5.5	0.8	5.7	0	5.6	0	5.8	0	6	0	5.8	0	5.9	0	6.1	0.9	6	0.6	9	4.6	2.3	3.9
18					5.5	0	5.7	0					5.5	0	5.7	0	5.7	1	5.6	0.7	6.9	0.3	2.3	2.8

MARMION CENTRAL

DEPTH (m)	June 9		July 5		July 13		July 21		July 28		Aug 9		Aug 24		Aug 30		Sept 22		Oct 5		Oct 20		March 9	
0	21.1	8.2	22.5	7.9	22.6	7.5	24	7.9	23.7	8	22.1	7.7	20.3	8	18.3	8.9	14.2	9.2	11.6	9.8	9.1	9.7	0.1	11.7
1	21.1	8.2	22.4	7.9	21.9	7.4	23.3	7.9	23.7	7.9	22.1	7.7	20.3	7.9	18.3	8.8	14.2	9.2	11.8	9.6	9.1	9.7	0.2	11.4
2	20.3	8.3	22.4	8	21.6	7.4	22.8	8.1	23.7	8	22.1	7.7	20.3	7.9	18.3	8.9	14.2	9.2	11.3	9.4	9.1	9.7	0.9	11.2
3	20.1	8.3	22.2	7.9	21.3	7.4	22.2	8.1	23.6	7.9	22	7.6	20.3	7.9	18.2	8.8	14.2	9.2	11.2	9.5	9.1	9.7	1.3	11.3
4	20	8.3	22.1	8	21.2	7.4	22.1	8.1	23.5	7.9	21.9	7.6	20.3	7.9	17.9	8.7	14.2	9.2	11.2	9.5	9.1	9.7	1.4	10.6
5	18.5	8.7	20.9	7.8	21.1	7.3	21.9	8	23.3	8	21.9	7.6	20.3	7.9	17.9	8.6	14.2	9.2	11.2	9.5	9.1	9.7	1.6	10.4
6	14.5	9.4	19.3	7.7	21	7.2	21.7	7.9	22.8	7.7	21.8	7.5	20.3	7.9	17.9	8.5	14.2	9.1	11.2	9.5	9.1	9.7	1.7	10.1
7	12	9	17.9	7.6	20.6	7.2	20.5	7.5	20.6	7.3	21.7	7.2	20.3	7.9	17.8	8.4	14.2	9.1	11.2	9.5	9.1	9.8	1.7	9.7
8	11.3	9.5	14.2	6	15.9	5.7	17.6	6.5	18.2	6.2	21.2	7.1	20.3	7.8	17.8	8.4	14.1	9.1	11.2	9.5	9.1	9.6	1.8	9.4
9	10.2	7.4	12.4	5.7	13.9	4.8	14.7	5.1	15.1	5	21	6	20.2	7.7	17.8	8.3	14	9.1	11.2	9.5	9.1	9.8	2	9.4
10	9.9	7	12.2	5.2	13.3	4.6	13.6	4.6	14.1	4.7	15.2	3.6	20	7.3	17.8	8.1	14	9.1	11.2	9.5	9.1	9.8		
11	9.7	6.8	12	4.9	12.4	4.1	12.6	3.9	13	3.4	13.8	2.6	18.3	4	17.3	7.2	14.1	9.1	11.2	9.5	9.1	9.8		
12	9.6	6.8	11.3	4.5	12	3.7	12.1	3.5	11.9	2.1	13	2.3	13.8	1	13.8	1.5	14	9.1	11.2	9.6	9.1	9.8		
13			11.2	3.9	11.4	3.2	11.4	2.6	11.6	1.9	11.8	0.6	13.1	1.4	12.2	1.4	14.1	9.2	11.1	9.5	9.1	9.9		
14			10.8	3.6	11.1	3.4			11.4	1.4	11.4	0.1	12.3	1.2	11.8	1.1			11	9.6	9.1	9.8		

MARMION NORTH

DEPTH (m)	June 10		June 29		July 5		July 13		July 21		July 28		Aug 9		Aug 24		Sept 1		Sept 22		Oct 5		Oct 19		March 9	
0	21.9	8.1	19.5	7.9	22.4	8	22.2	7.7	24.6	8	24.5	8	22.3	7.4	20.6	7.8	19.2	8.7	14.1	8.9	11.6	9.1	9.3	8.8	0	11.6
1	21.8	7.9	19.5	7.9	22.4	8	21.8	7.6	23.7	8.2	24.5	8	22.3	7.4	20.6	7.8	18.7	8.5	14	8.8	11.6	9.1	9.2	8.8	0.2	10.9
2	21.8	7.9	19.4	7.9	22.3	8	21.5	7.6	22.7	8.2	24.5	8	22.3	7.4	20.6	7.8	18.5	8.4	14	8.8	11.5	9	9.2	8.7	1.2	10.4
3	21.7	7.9	19.4	7.9	22.3	8.1	21.5	7.5	22.2	8.1	24.3	8	22.3	7.4	20.6	7.8	18.4	8.3	14	8.8	11.4	9	9.2	8.7	1.5	10.2
4	17.8	9	19.3	7.9	22.2	8.1	21.5	7.5	22.1	8.1	23.8	8	22.2	7.4	20.6	7.8	18.4	8.3	14	8.8	11.4	9	9.2	8.7	1.5	10.1
5	15.6	9.5	19.3	7.9	22	8	21.4	7.5	21.8	8	23.2	8.2	22.2	7.3	20.6	7.8	18.3	8.2	14	8.8	11.3	9	9.2	8.7	1.6	9.9
6	14	9.5	19.3	7.8	21.7	8	21.2	7.4	21.5	8	23	8	22	7.1	20.5	7.6	18.1	8	14	8.8	11.3	9	9.2	8.7	1.8	9.5
7	12.4	9.3	19.1	7.6	19.8	7.8	20.2	6.8	20.4	7.7	22.4	7.6	21.7	6.9	19.6	6.8	18	7.9	14	8.8	11.2	8.9	9.2	8.7	1.8	9.4
8	11.3	9.1	16.4	7.7	18.3	7.5	17.7	6.6	17.9	6.7	16.4	5.2	20	4	19.1	6.4	17.9	7.6	14	8.7	11.1	8.8	9.2	8.6	1.9	9
9	10.7	8.9	14.7	7.2	16	6.9	15.2	6.8	14.7	6.4	15.3	5.9	16.4	4.2	18.6	6.3	17.5	6.6	14	8.7	11.1	8.8	9.2	8.6	2	8.5
10	10	8.8	12.4	7.8	14.8	7	13.4	6.6	12.3	6.1	12.2	5.1	13.4	3.6	16.3	3.6	15.6	5.3	14	8.4	11	8.8	9.2	8.6	2.2	8
11	9.4	8	11.2	7.3	10.3	6.4	11	5.7	10.8	4.9	11	4.8	11.3	3.6	12	3.2	12.2	3	13.9	8.2	11.1	8.8	9.2	8.6	2.3	7.6
12	8.6	6.9	10	6.1	9.6	5.5	9	3.9	9.8	3.9	9.7	2.7	10.2	2.4	10.7	2.3	10.3	2.3	11.9	1.4	11.1	8.7	9.2	8.7	2.3	7.3
13	7.7	6.5	9.3	5.8	8.1	3.6	7.7	1.6	8.5	2.2	8.4	0.8	8.9	0	8.9	0.8	9.4	1.6	8	1	10.9	8.4	9.2	8.6	2.4	6.6
14	6.7	3.4	8.7	4.6	7.4	1.3	7.7	0	7.3	0	7.5	0	7.2	0	7.8	0	8.3	0.8	6.9	1	9.8	1.9	9.2	8.5	2.6	6.3
15	5.9	1.2	7.6	2.5	7	0	6.1	0	6.5	0	6.7	0	6.8	0	6.7	0	7.1	0.8	6.6	1.1	7.3	0.7	8.8	8.2		
16			6.5	0.2	6.6	0					6.4	0			6.5	0	6.8	0.8	6.5	1			8.4	2.2		

ANDERSON DAM

	June 9		June 29		July 5		July 13		July 21		July 28		Aug 9		Aug 24		Sept 1		Sept 22		Oct 5		Oct 20		March 9	
0	21.5	8.2	19.4	7.9	22.3	8.2	21.9	7.7	24.8	8	23.8	8.1	22.1	7.4	20.5	8.1	18.8	8.7	13.8	9.6	10.6	10	8.1	9.9	0	11.4
1	21.3	8.2	9.3	7.9	22.2	8.2	21.7	7.7	23.3	8	23.8	8.2	22.1	7.4	20.5	8	18.7	8.6	13.8	9.6	10.6	10	8	9.9	0	11.4
2	20.6	8.2	19.3	7.9	21.7	8.2	21.3	7.6	22.5	8.2	23.8	8.2	22.1	7.4	20.5	8	18.6	8.7	13.8	9.6	10.3	10	8	9.9	0.8	10.4
3	20.4	8.3	19.3	7.9	20.9	8	21.3	7.7	22.1	8.1	23.5	8.1	22	7.4	20.5	8	18.3	8.6	13.7	9.6	10.1	10	8	9.9	1.4	9.8
4	20.3	8.3	19.3	7.9	20.3	8.1	21.2	7.6	22	8.1	22.7	8	22	7.4	20.4	8	18.2	8.5	13.7	9.6	10.1	10	8	9.9	1.7	8.7
5	15	9.1	19.3	7.9	20	8	21.1	7.5	21.7	7.9	21.6	7.7	21.8	7.3	20.4	7.9	18.2	8.3	13.7	9.6	10.1	10	8	9.9	2.4	7.6
6	13.4	8.5	19.2	7.8	19.1	7.5	21	7.4	21	7.7	20.5	7.2	21.6	7.1	20.4	7.9	17.9	8.1	13.7	9.5	10	9.9	8	9.9	2.9	5.7
7	12.6	7.3	19	7.6	18.2	7.1	19.1	6.3	20.6	7.6	20.4	6.8	20.7	5.6	20.4	7.8	17.7	8	13.7	9.5	10	9.9	8	10	3.1	5
8	11.8	6.1	15.5	5.9	14.8	5.5	17.1	5.3	20.2	7	16.6	3.1	19.3	4.5	20.4	7.8	17.6	7.5	13.7	9.4	10	9.9	8	10.1	3.3	4.7
9	11.6	5.1	13.5	5	12.1	2.8	14.3	2.6	15.8	3.1	14.3	0	14.5	0	20.3	7.5	16.9	7.5	13.6	9.4	9.8	9.8	8	10	3.5	4.3
10			12	1.3	11.5	0			14.8	2	12.6	0	11.5	0	14.6	0.4	15.8	2.1	13.6	9.4	9.8	9.9	8	10.1	3.6	4.3
11															12.3	0.4	11.3	0.7	13.6	9.5	9.4	10.1	8	10.2		

LOWER SEINE

DEPTH (m)	June 10		July 5		July 13		July 21		July 27		Aug 9		Aug 24		Aug 30		Sept 22		Oct 5		Oct 19		March 9	
0	21	8.3	23	8.1	22.4	7.8	23.8	7.7	24.3	8	22.3	7.6	20.8	8	18.9	8.8	14.2	9.2	11.8	8.8	9.3	9.5	0.1	11.2
1	21	8.3	22.7	8.1	22.1	7.8	23.7	8	24.2	8	22.3	7.6	20.7	7.9	18.9	8.8	14.2	9.1	11.8	8.7	9.2	8.5	0.4	11
2	20.9	8.3	22.4	8.1	22	7.8	22.8	8.2	24	8	22.3	7.6	20.6	7.9	18.9	8.7	14.2	9.1	11.5	8.7	9.2	8.3	1	10.5
3	20.9	8.3	21.8	8.1	21.8	7.6	22.4	8.2	24	8	22.2	7.6	20.6	7.9	18.5	8.7	14.2	9.1	11.4	8.6	9.2	8.5	1.6	10.3
4	20.8	8.3	20.2	8.1	21.7	7.5	22.1	8	23.8	8	22.2	7.6	20.5	7.9	18.3	8.7	14.2	9.1	11.3	8.6	9.2	8.5	1.6	10
5	15.5	10	19.9	8	21.6	7.4	21.8	7.8	23.4	8.2	22.1	7.6	20.5	7.9	18.2	8.6	14.2	9.1	11.2	8.6	9.2	8.5	1.7	9.8
6	17.5	9.5	18.3	7.7	21.5	7.5	21	7.5	22.1	7.9	22.1	7.5	20.5	7.8	18.2	8.5	14.2	9.1	11.2	8.6	9.2	8.5	1.8	9.7
7	12.3	9.4	17.2	7.4	17.5	6.9	19.4	7	22.1	7.4	22	7.5	20.5	7.6	18.1	8.5	14.1	9.1	11.2	8.6	9.2	8.5	1.9	9.7
8	11.2	8.9	14.6	6.8	15.1	6.8	15.1	7	19.1	6.8	22	7.4	20.2	7.6	18.1	8.4	14.2	9	11.2	8.5	9.2	8.5	1.9	9.7
9	10.4	9.4	13	6.3	13.6	7.3	12.4	6.8	14.8	6.6	14.2	4.9	18.1	3.7	18	9.2	14.1	8.6	11.2	8.5	9.2	8.5	2	9.2
10	10.1	8.3	11.6	5.4	11.7	7	10.9	5.8	11.8	6.2	11.4	4.5	12.8	4.1	16.9	5.7	14	8.6	11.1	8.3	9.2	8.5	2.1	8.9
11	9.5	7.9	11.2	5.1	10	5.7	9.9	5	10.2	5.1	10	3.8	11.6	4.6	11.4	4.7	13.4	5	11.1	8	9.2	8.5	2.1	8.5
12	9.5	7.7	10.9	4.6	9.1	4.9	9.2	4.5	9.8	4.6	9.6	3.1	10	3.8	10.2	4.4	10.3	2.7	11	8.1	9.2	8.5	2.2	8.2
13	9.1	7.4	10.6	3.8	8.5	3.5	8.7	3.9	9	3.8	9.3	2.8	9	3	9.3	3.9	9.9	1.7	10.8	6.9	9.2	8.5	2.3	8
14	9.6	6.9	10.3	3.3	8.2	3.1	8.3	2.9	8.4	2.6	8.7	2.5	8.6	2.4	8.6	3.2	8.6	1.6	10.7	6.5	9.2	8.5	2.4	7.4
15	5.5	6.8			8	2.9	8	2.2	8	1.6	8.6	2	8.2	1.7	8.2	2.1	8.1	1	8.6	0.6	9.2	8.5	2.6	6.9
16	8.5	6.8			7.8	2.1	7.8	1.2	7.9	0.8	8.5	1.8	7.9	0.9	7.9	1.4	7.4	1	9	0.6	9.2	8.5		
17	8.4	6.7			7.6	0.8	7.6	0.5	7.8	0	8.4	1.6	7.7	0	7.8	1.3	7.3	1.1			9.2	8.5		
18	7.7	5.4			7.5	0	7.4	0	7.6	0	8.3	0.8	7.5	0	7.6	1.2	6.9	1.1			9.1	8.5		
19	7.4	4.9			7.4	0	7.4	0	7.4	0	8	0	7.3	0							8.7	4.4		
20	7.1	3.2					7.1	0			7.7	0												

MOOSE LAKE

DEPTH (m)	June 9		June 29		July 5		July 13		July 21		July 28		August 9		August 24		Sept 1		Sept 22		Oct 5		Oct 20	
0	22.7	7.3	20.8	7.4	22.9	7.9	22.8	7.4	24	7.8	24.2	8.1	22.6	7.4	21.3	7.8	19.7	8.7	14.8	8.9	12	9.5	8.6	9.7
1	22.5	8	20.6	7.5	22.9	7.8	22.7	7.5	23.6	7.9	24.2	8	22.6	7.4	21.2	7.7	19.6	8.7	14.7	8.8	11.8	9.4	8.6	9.7
2	22.1	8.2	20.5	7.4	22.6	7.9	22.5	7.5	22.7	7.9	24.2	8	22.5	7.4	21.2	7.7	19.4	8.6	14.7	8.8	11.7	9.3	8.6	9.6
3	21.9	8.1	20.5	7.4	22.5	7.8	22.3	7.5	22.5	7.9	24.1	8.1	22.5	7.4	21.2	7.7	19.1	8.5	14.7	8.8	11.7	9.3	8.6	9.6
4	21.5	8	20.5	7.5	22.2	7.8	22.3	7.5	22.5	7.7	24	8.1	22.5	7.4	21.2	7.6	19	8.4	14.7	8.8	11.7	9.3	8.6	9.6
5	21.2	8	20.3	7.5	21.7	7.8	22.2	7.5	22.2	7.6	23.6	8	22.4	7.2	21.2	7.6	18.9	8.3	14.7	8.8	11.7	9.3	8.6	9.6
6	21	8	20.1	7.4	211.	7.8	22.2	7.4	22.2	7.5	23.4	8	22.3	7.3	21.2	7.5	18.9	8.2	14.7	8.8	11.7	9.3	8.6	9.6
7	20.7	7.8	20.2	7.5	21	7.8	22.1	7.2	22.2	7.6	23.4	8	22.3	7.3	21.1	7.4	18.8	8.1	14.7	8.8	11.6	9.3	8.6	9.6
8	20.4	7.6	20.1	7.4	20.9	7.8	22.1	7.3	22.1	7.3	23.2	7.8	22.2	7.2	21.1	7.4	18.7	8.1	14.7	8.8	11.6	9.3	8.6	9.6
9	19.9	7.5	20	7.4	20.6	7.4	22	7.2	22	7.3	23	7.5	22.2	7.2	21.1	7.2	18.5	8.1	14.7	8.8	11.5	9.2	8.6	9.6
10	19.8	7.4	20	7.4	20.5	7.3	21.9	7.1	21.8	7.2	22.9	7.4	22	7.1	21	7.3	18.4	8	14.7	8.8	11.4	9.2	8.6	9.6
11	19.1	7.1	19.9	7.3	20.3	7.2	21.8	7.1	21.6	6.8	22.8	7.2	21.9	7	21	7.2	18.4	8.1	14.7	8.7	11.3	9.2	8.6	9.6
12	18.6	6.6	19.9	7.2	20.1	7.2	21.6	7.3	21.6	6.5	22.4	6.8	21.8	7	21	7.3	18.3	8.1	14.7	8.7	11.2	9.2	8.6	9.4
13	17.2	6.5	19.7	7.4	19.9	6.4	21.5	7.2	21.2	6.2	22	5.8	21.6	6.8	20.9	7.2	18.2	8	14.6	8.6	11.2	9.2	8.6	9.5
14	13	6.5	19.5	7.2	19.3	6	21.2	7.2	20.2	5.6	21.3	5	21.6	6.4	20.8	7.4	18.1	7.9	14.6	8.5	11.1	9.2	8.5	9.5
15	7.5	6.6	18.8	6.4	18.6	5.2	19.1	4.2	16.8	2.5	19.1	2.7	20.4	4.8	20.5	7.3	18	7.7	14.6	8.4	11	9.2	8.4	9.4
16	5.6	6.7	10.9	4.6	10.6	4.1	12.7	3.2	11	2.6	10.2	3.5	17.4	1.3	15.9	0.7	17.8	7.3	14.6	8.2	10.9	9.2	8.5	9.3
17	5.5	6.6	6.8	5.5	6.5	5	7.4	4.2	7.4	4.2	7.8	4	8.5	3	9.6	3	16.5	5.6	14.5	7.9	10.8	9.1	8.5	9.1
18	5.2	6.6	5.7	5.9	5.6	5.5	6.3	4.7	6.1	4.9	6.3	4.5	6.5	3	7.3	3.6	9	3.7	13.4	6.6	10.7	8.8	8.4	8.9
19	5	7	5.3	6	5.3	6	6.2	4.8	5.5	5.3	5.9	4.9	5.8	4.5	6.4	4.2	6.4	4.2	7.7	7.4	10.2	5.5	8.3	8.9
20	4.8	7	5.1	6.5	4.7	6	5.9	5	5.1	5.5	5.3	5.3	5.3	4.7	5.6	4.6	5.4	6	6	4.6	6.2	4.6	6.4	8.8
21	4.7	7.1	4.7	6.3	4.7	5.9	5.7	5.1	4.8	5.5	4.9	5.3	4.9	4.6	5.3	5.1	5	6.3	5.2	5.2	5.1	4.6	8.3	8.8
22	4.5	7	4.6	6	4.6	5.9	5.2	5.5	4.6	5.2	4.6	5.2	4.7	4.6	4.7	5.7	4.7	6.3	5	5.4	4.7	4.7	8.3	8.7
23	4.4	7	4.4	5.9	4.2	5.8	4.9	5.8	4.5	5.2	4.5	5.2	4.5	4.5	4.5	5.6	4.5	6.5	4.2	5.8	4.6	4.5	4.7	4.2
24	4.5	7	4.4	6	4.3	5.6	4.7	5.8	4.5	5.2	4.3	5.3	4.4	4.5	4.4	5.8	4.3	6.7	4.4	5.8	4.5	4.6	4.6	4.2
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